Innovative Structural Slab Practices – Voided Slabs

Session sponsored by ACI/ASCE 421

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Session Moderator

April 14, 2013
Minneapolis, MN

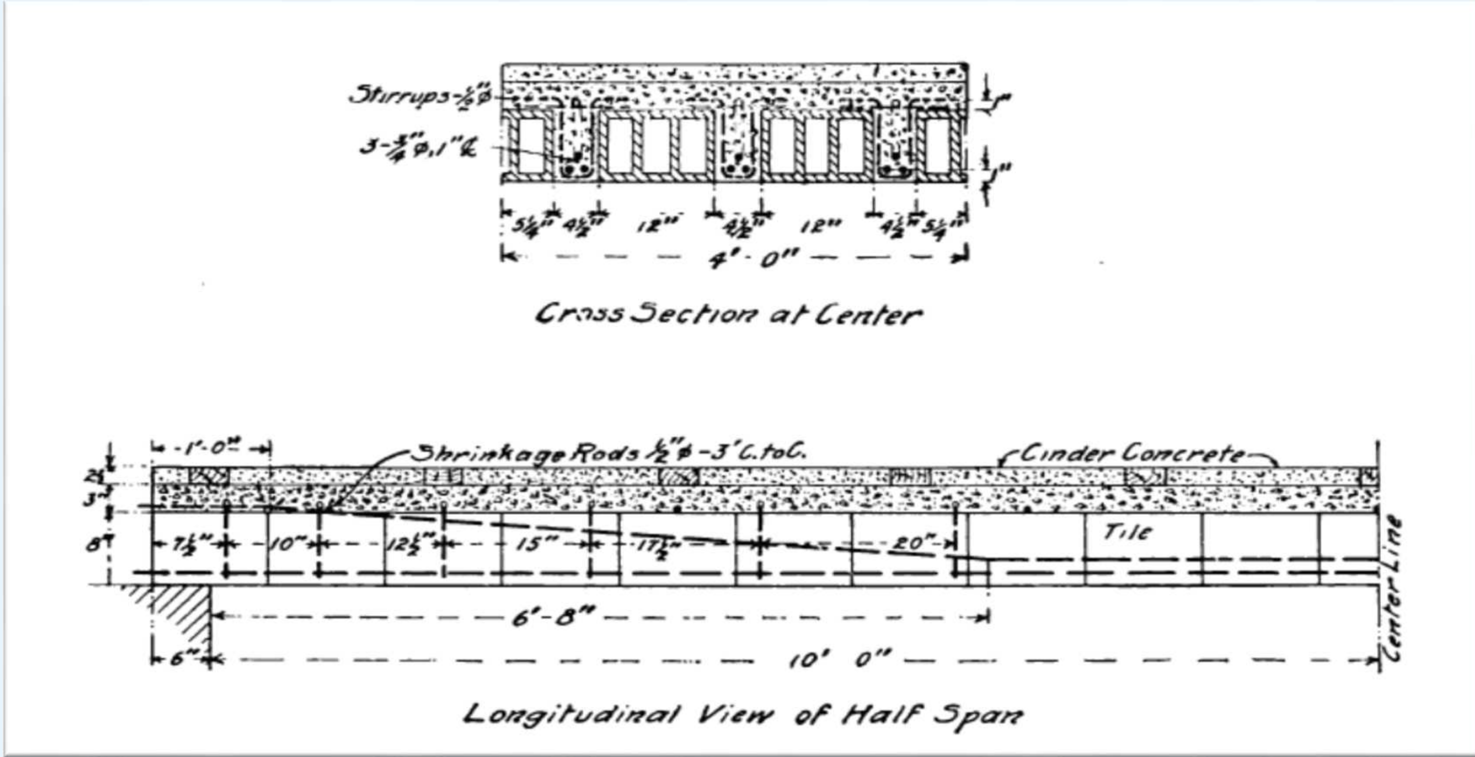
Twin Cities Spring 2013 Responsibility in Concrete Construction

Agenda

- Historical Overview
- CRSI Design Guide for Voided-Slabs
- New Trends – Case Studies
  - Miami Art Museum
  - UW LaBahn Arena
  - Harvey Mudd College

Historical Overview

Tests of RC Hollow Tile (Purdue U.- Oct. 1907)



Source: W. K. Hatt

Material Properties

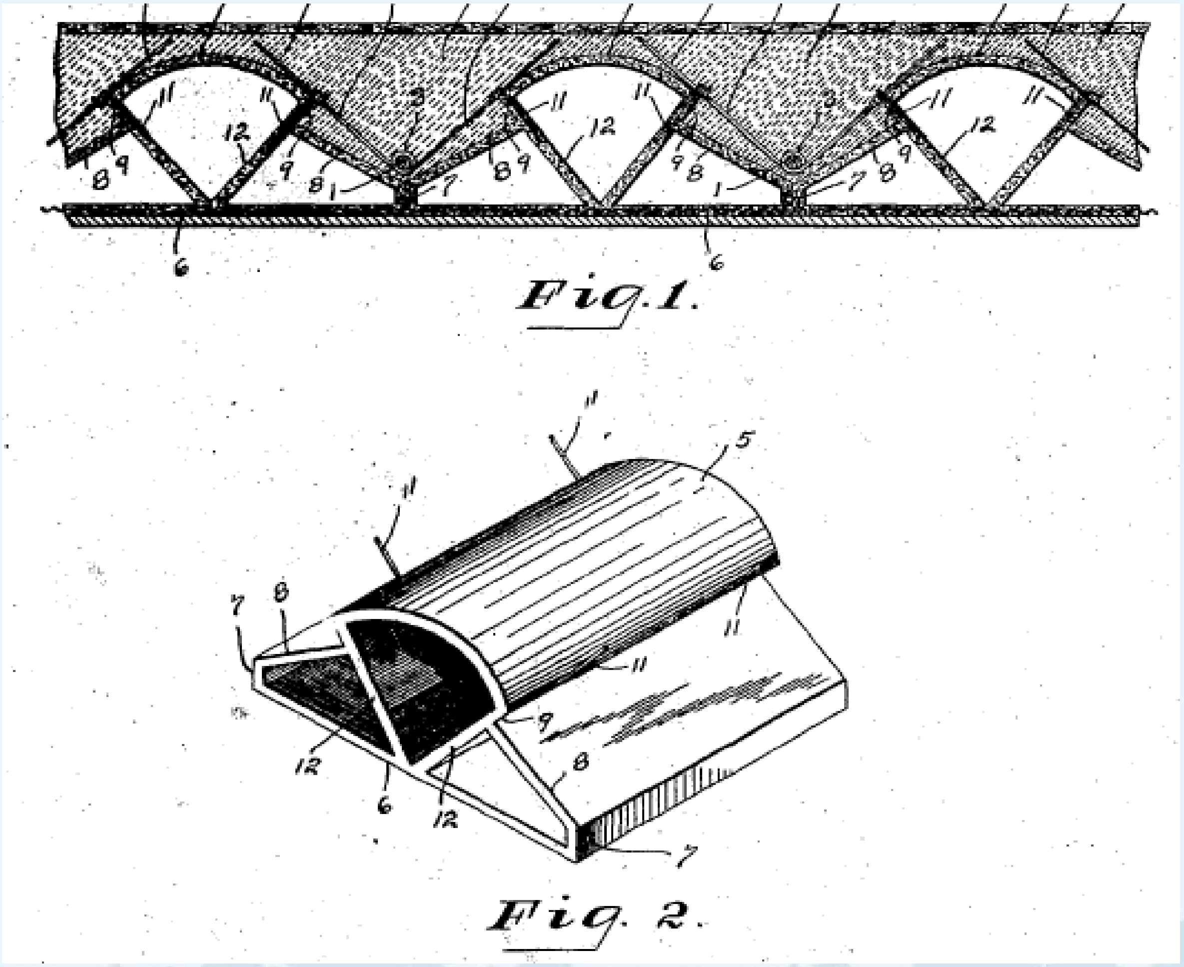
- Tension in steel – 16,000 psi
- Concrete f' c – 750 psi
- Shear in Concrete – 75 psi
  - One-way shear $2\sqrt{(f'c)} = 55$ psi

Loading the slab

Load Test Results

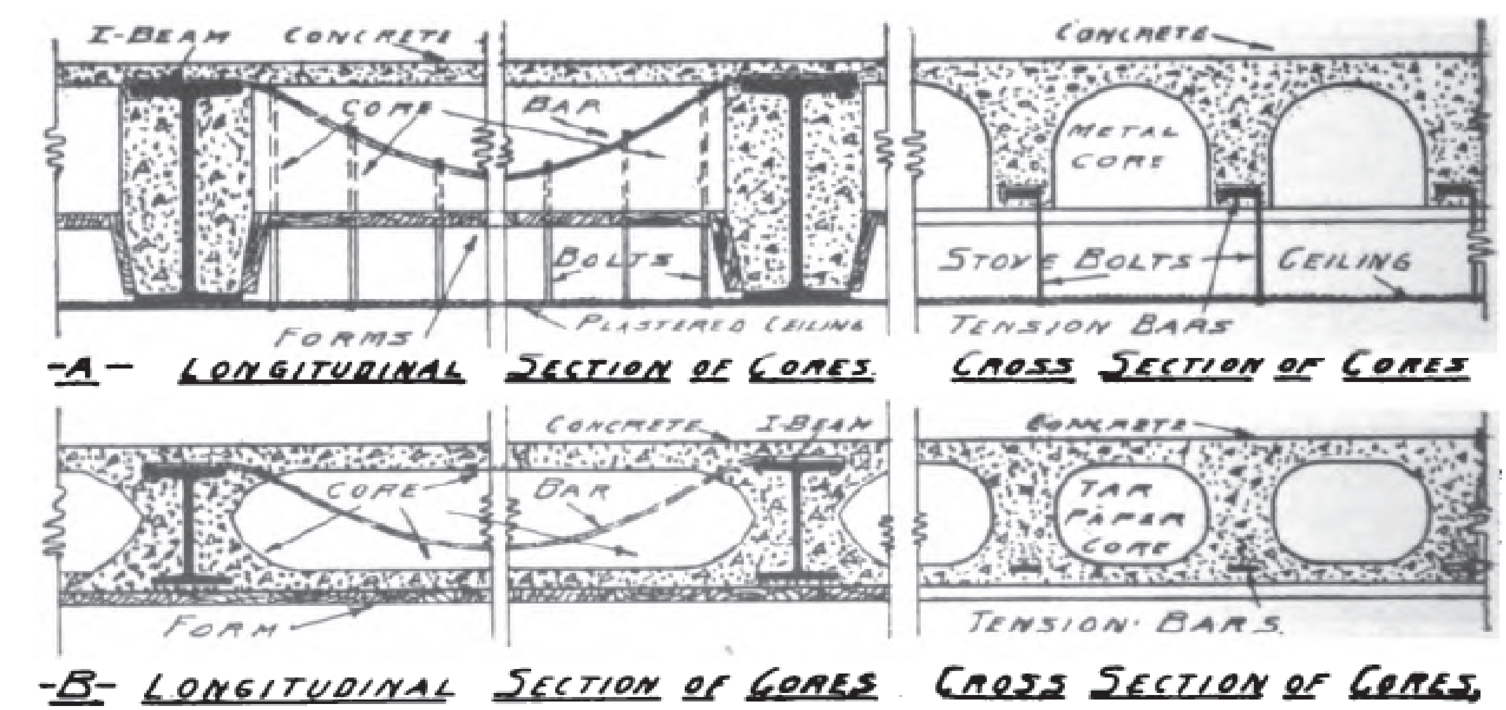
- Slab designed for 100 psf (LL)
- Maximum LL
  - 510 psf at yield
  - 710 psf at end of test
- Max. Deflection
  - 3" deflection caused slab to bottom out ~ L/75

Purdue University - Oct. 1907



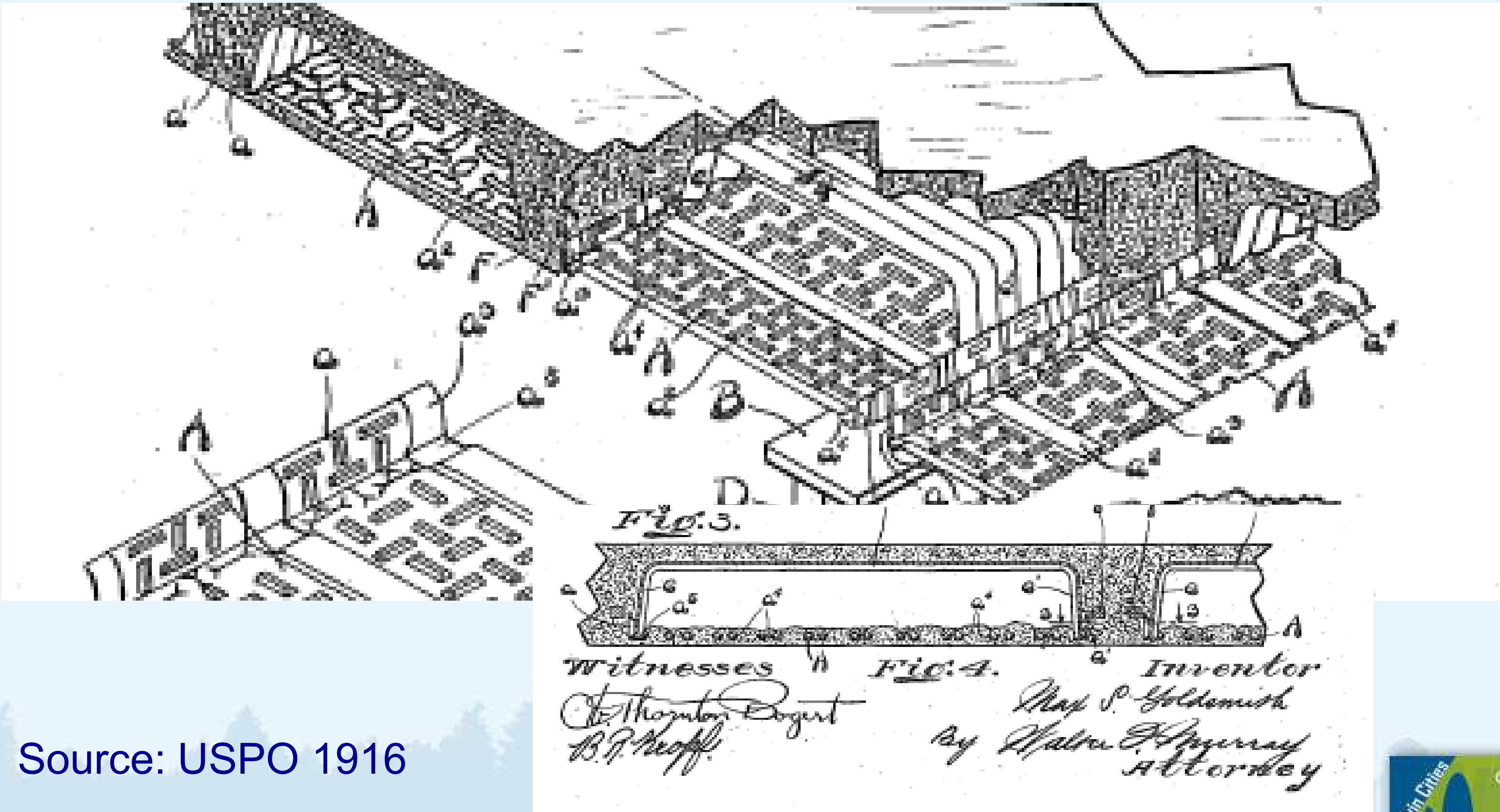
Source: USPO 1909

Use of Cores in RC Floors



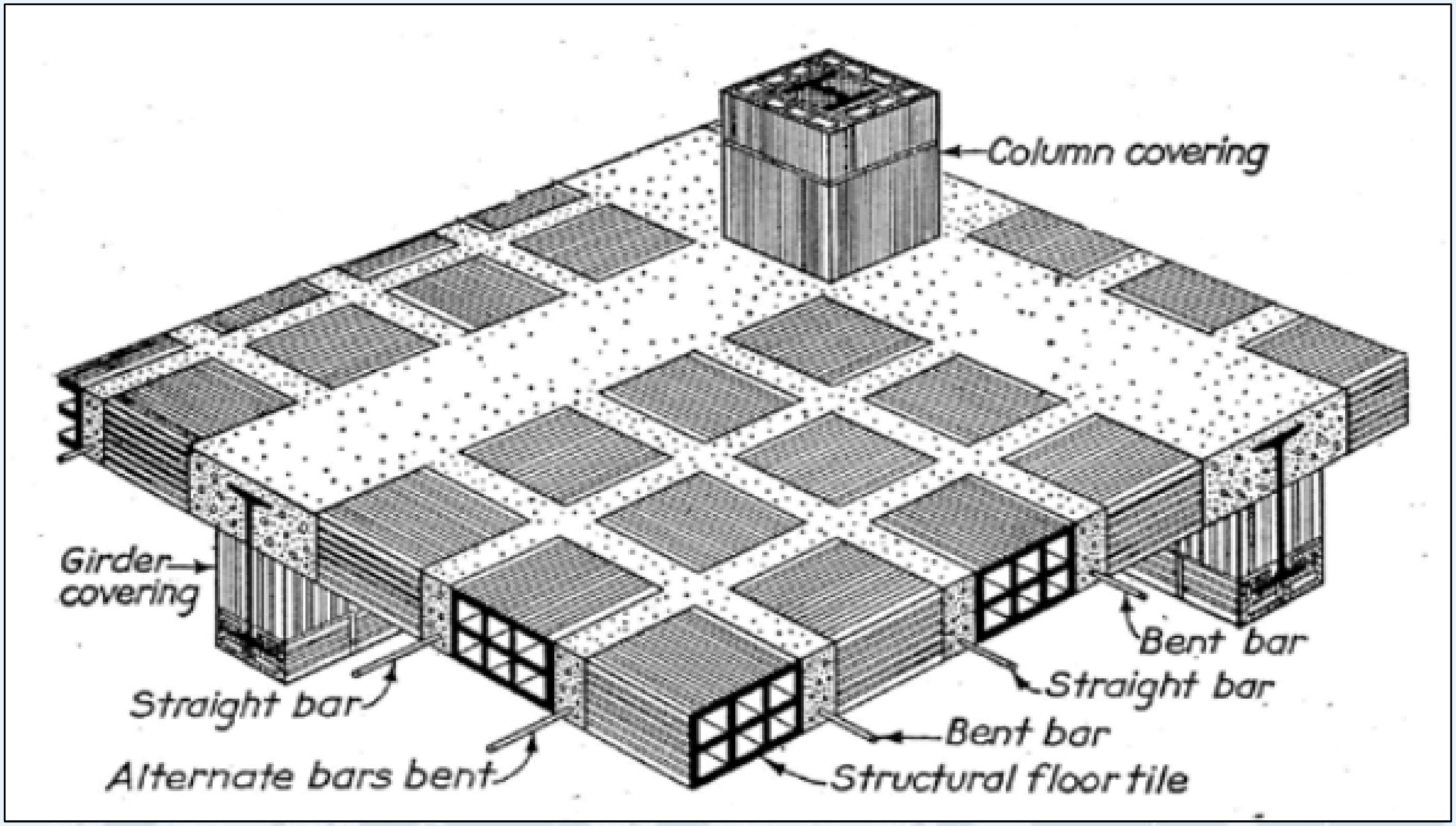
SKETCHES SHOWING USE OF METAL AND PAPER CORES

Source: Concrete-Cement Age: August 1914



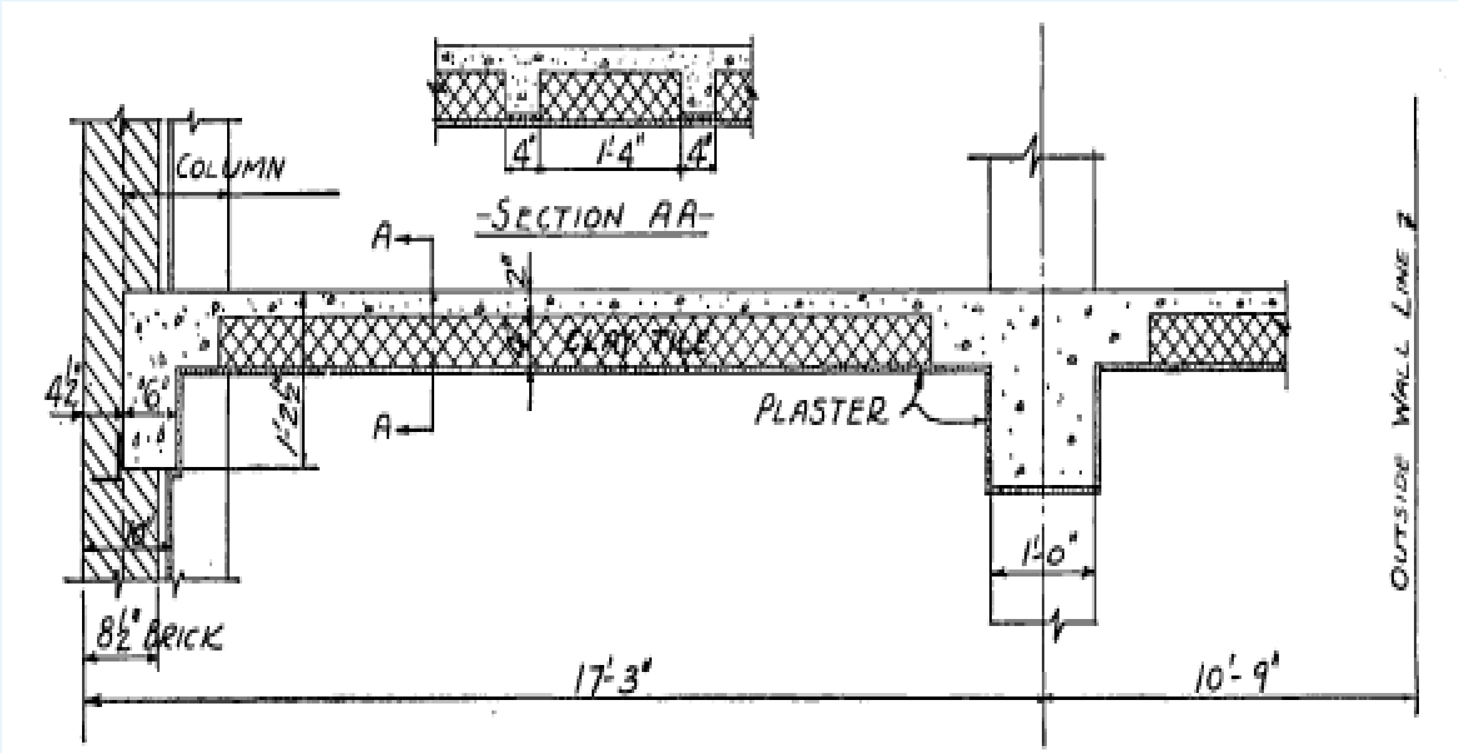
Source: USPO 1916

(two-way) slab - 1915



Structure Magazine (2008)

Ida B. Wells Housing (Chicago)



Source: Journal of ACI (Nov, 1941)

Ida B. Wells Housing (Chicago)

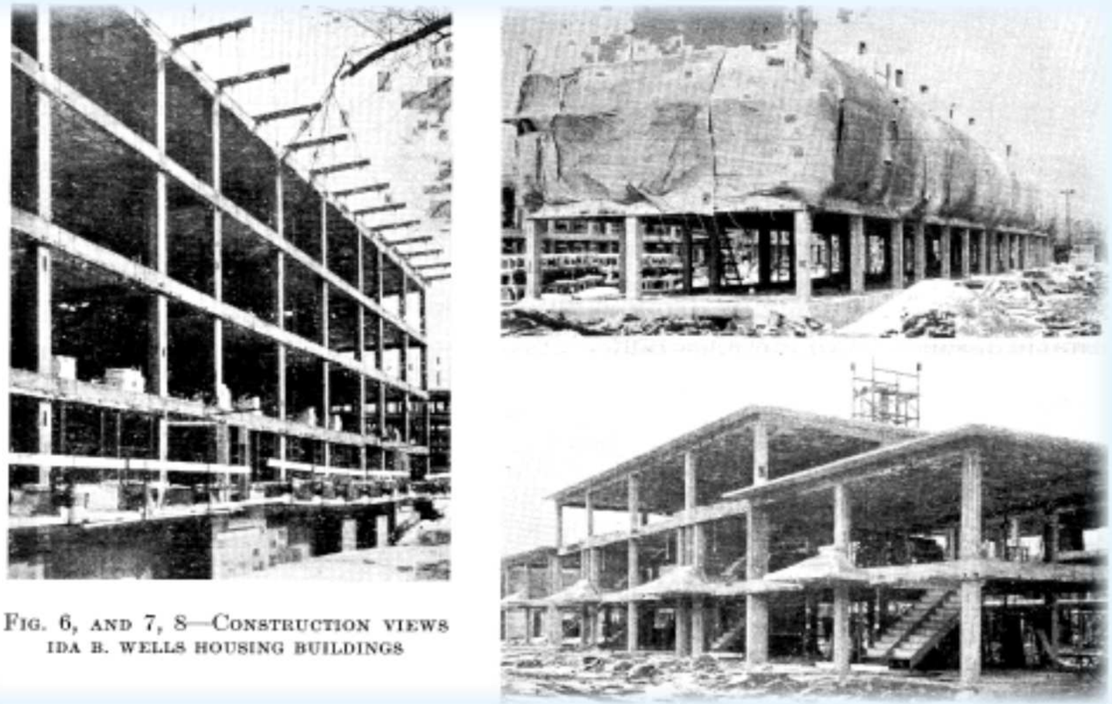


FIG. 6, AND 7, 8—CONSTRUCTION VIEWS IDA B. WELLS HOUSING BUILDINGS

Journal of ACI (Nov, 1941)

- 124 Buildings
- 3,000 tons of rebar
- 46,000 cy of concrete

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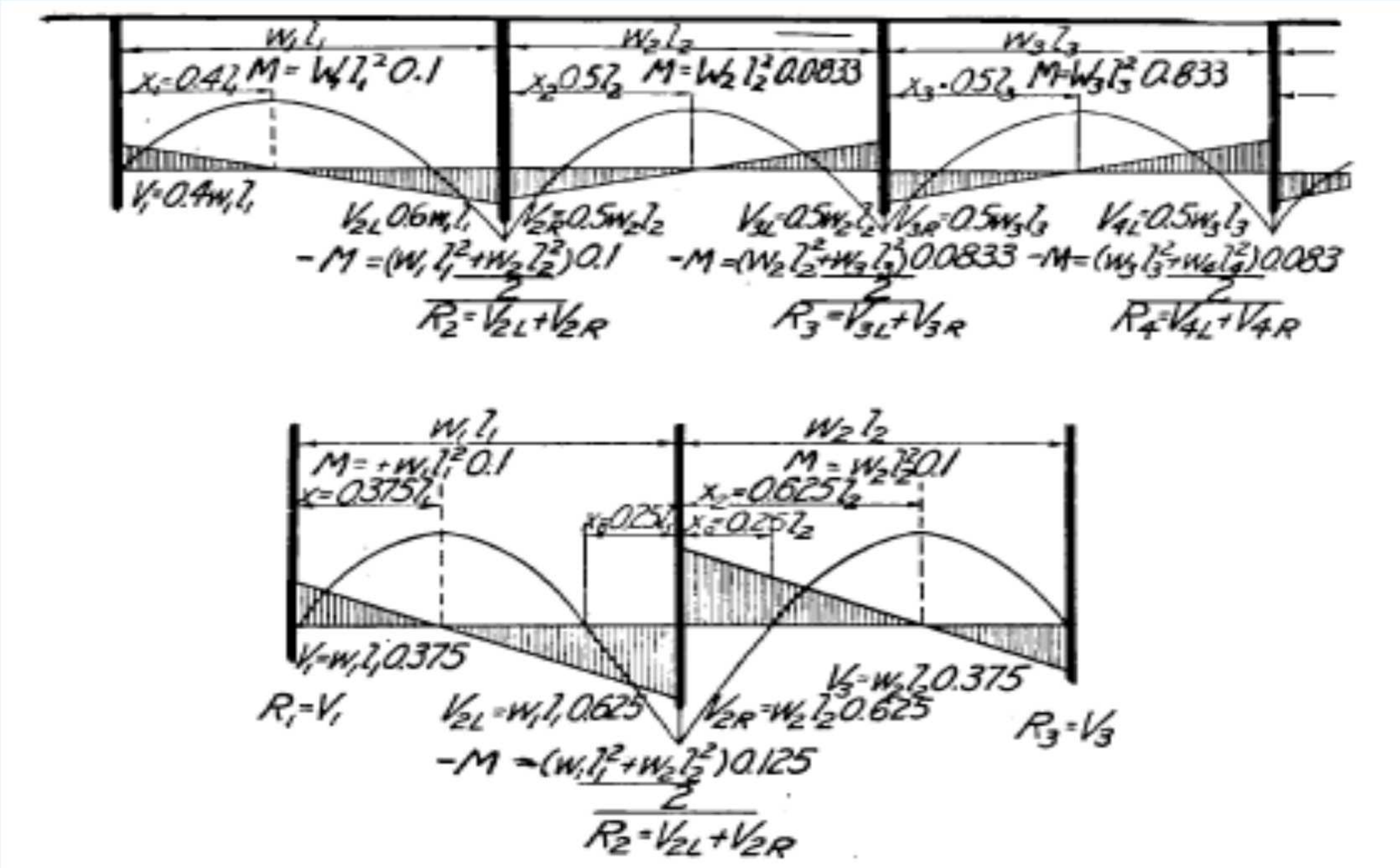


Journal of ACI (Nov, 1941)

Fig. 1 — Rendering shows design concept for a 688,000 sq ft operations center Austin's Western District in Irvine, Calif., has designed and is building for Security Pacific National Bank.

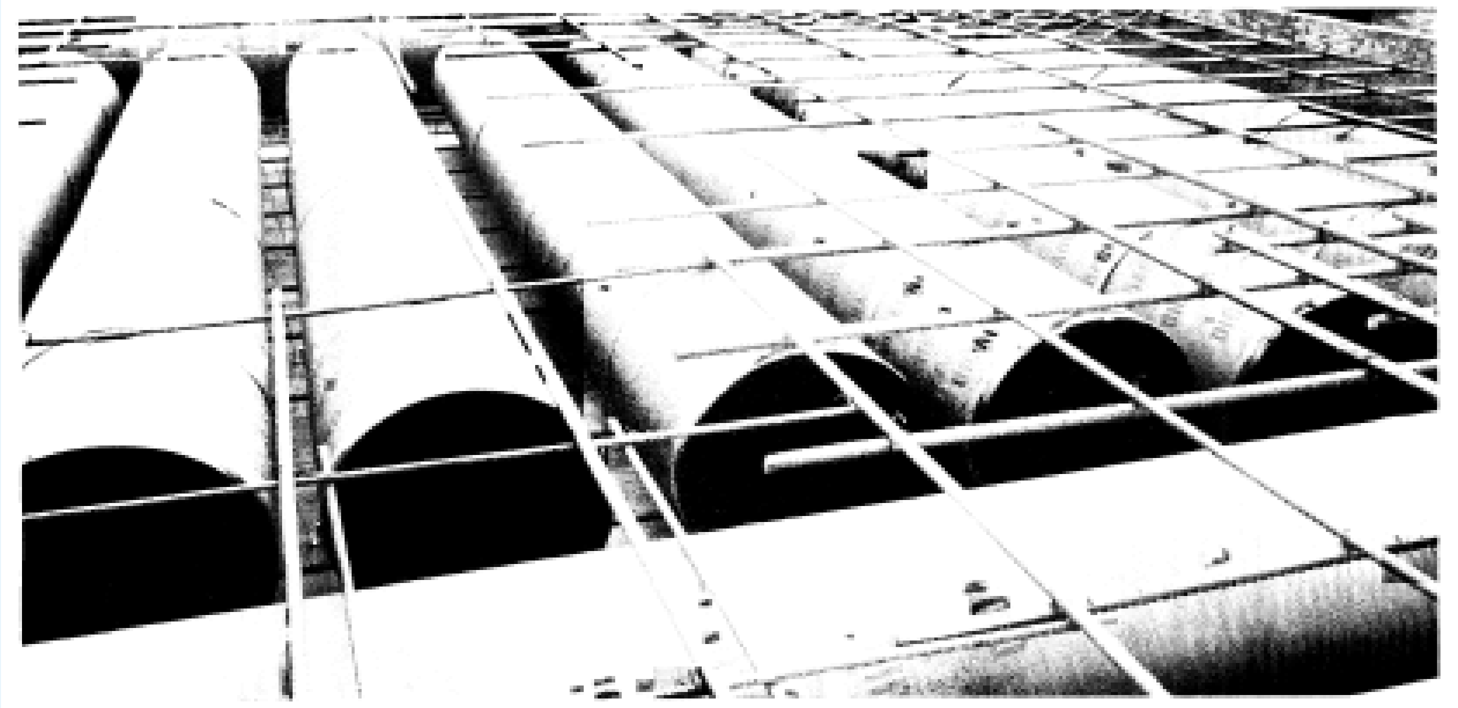
Voided Flat Plate Slabs Reduce Cost and Speed Up Construction

by H. J. Benet and Bill Williams, Jr.

This article describes an unbiased approach utilized to select the best combination of materials and types of structures for an operations center building. After the concrete voided flat plate slab system was selected as the most appropriate type of structure, it is shown how the final design was made. A brief description of the innovations incorporated in the actual construction and how they were developed and tested prior to their usage is also explained. The completion of the concrete structure ahead of schedule and below the estimated cost proved all the predictions and attested the reaching of all the objectives.

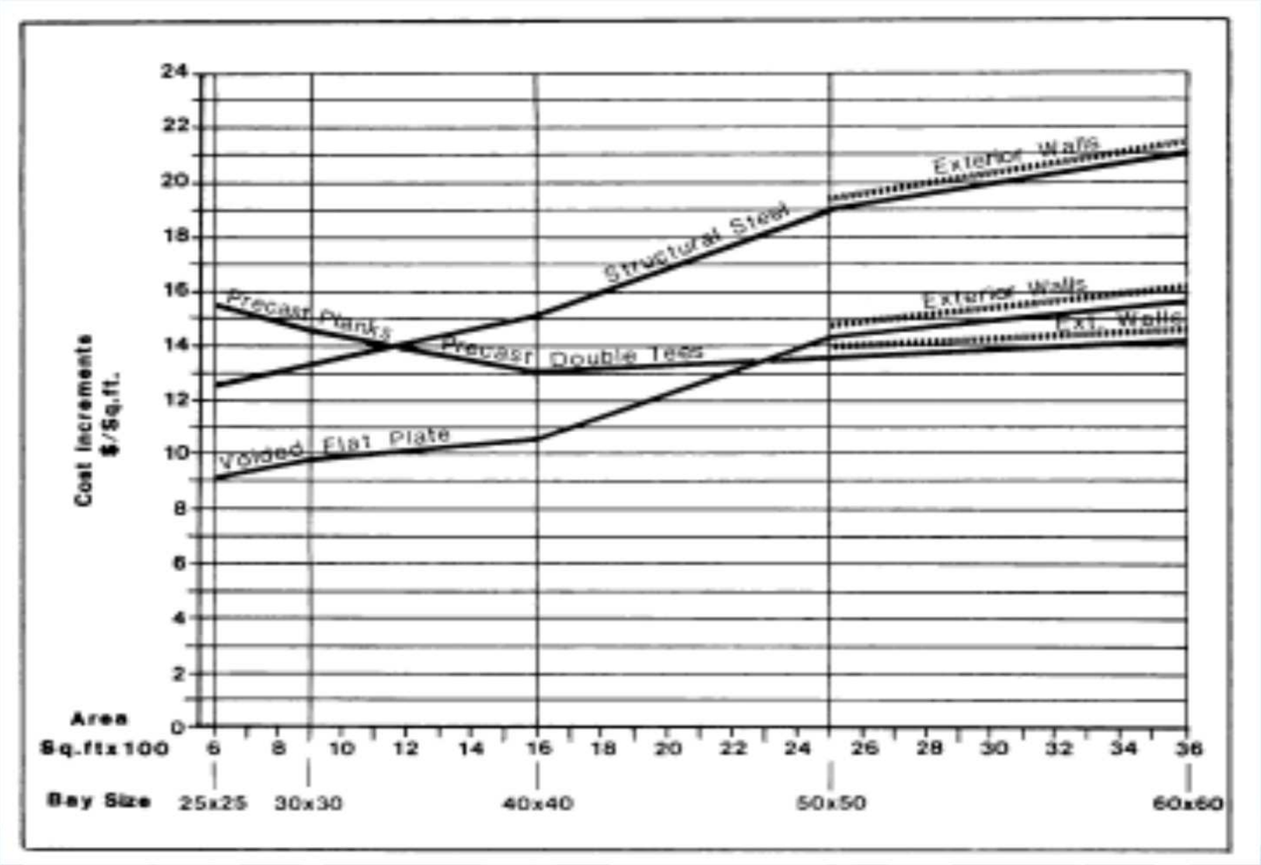
Keywords: computer programs; concrete construction; **costs;** earthquake resistant structures; **flat concrete plates;** flat concrete slabs; fly ash; **framing systems;** hollow core slabs; models; **office buildings;** quality control; reinforced concrete; structural design.

CI Article (May 1983)

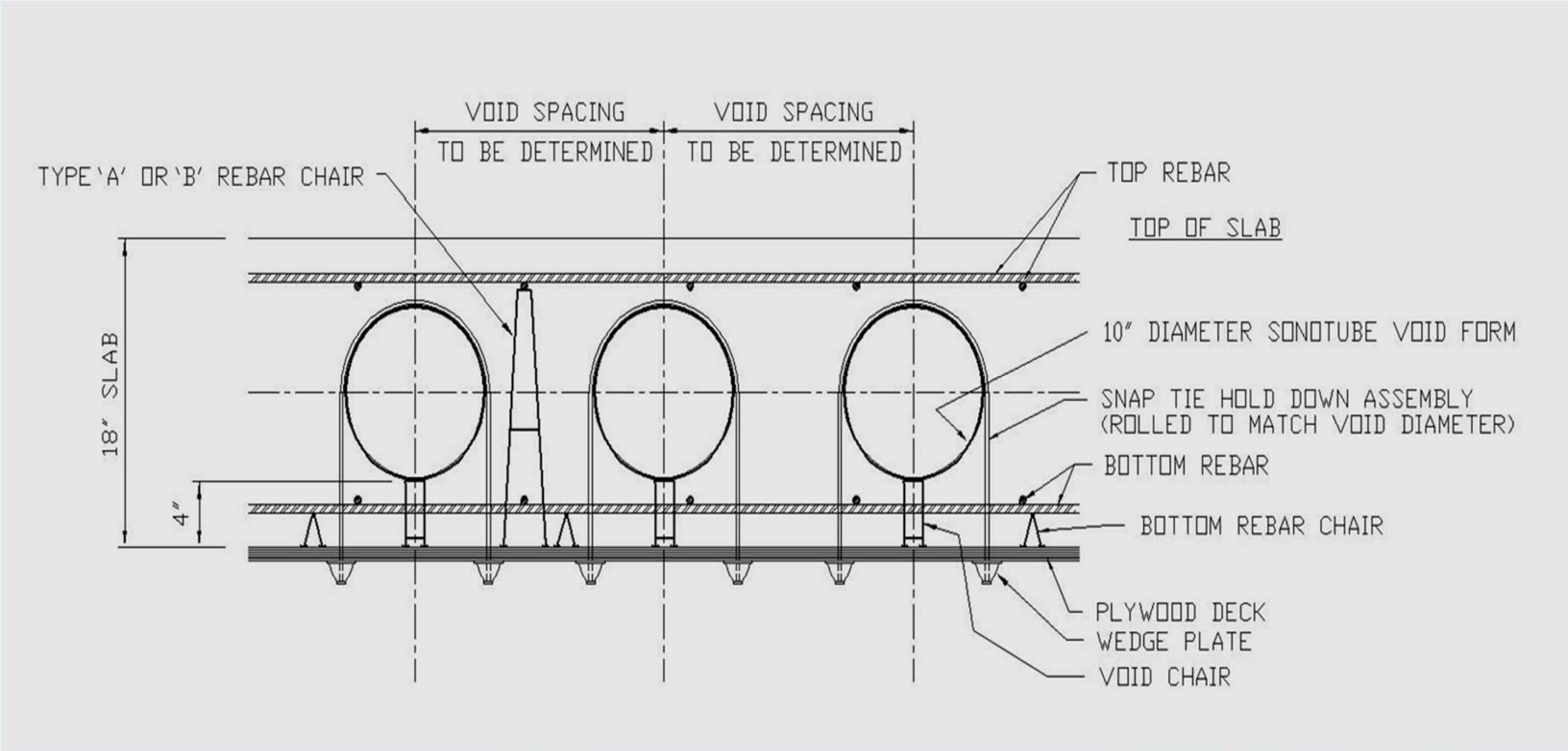


688,000 sq. ft. “Low-rise”
40 feet Unobstructed Spans
Heavy LL (125 PSF)

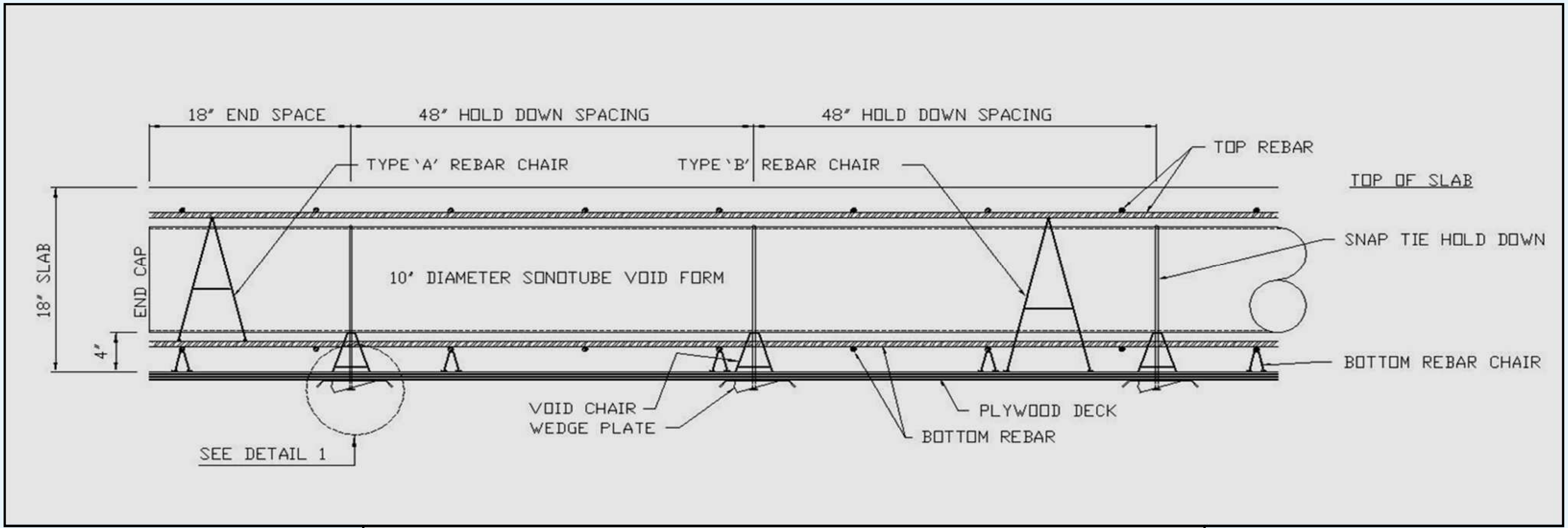
Cost (sq. ft.) Comparison

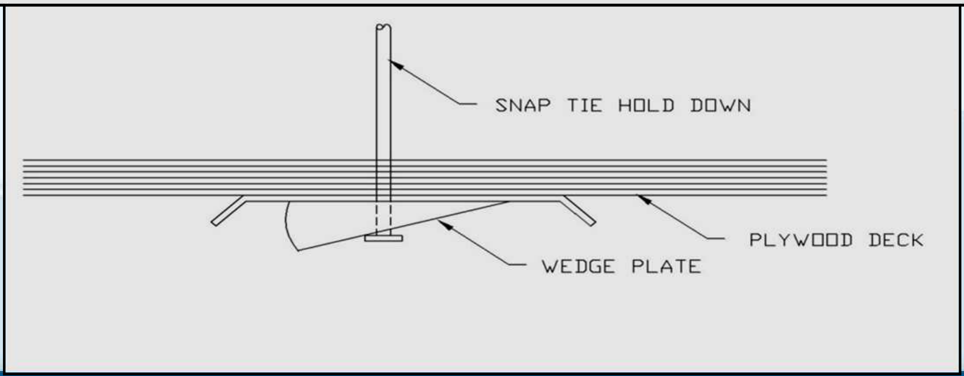


Anchoring The Voids

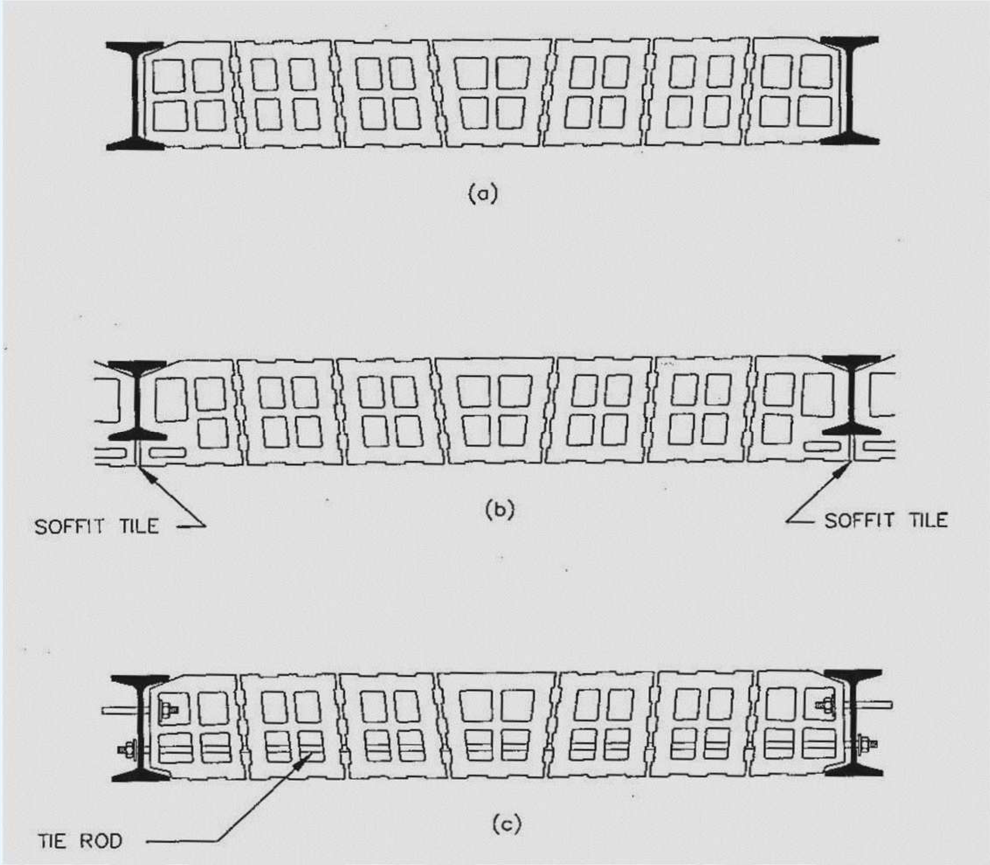


Anchoring The Voids

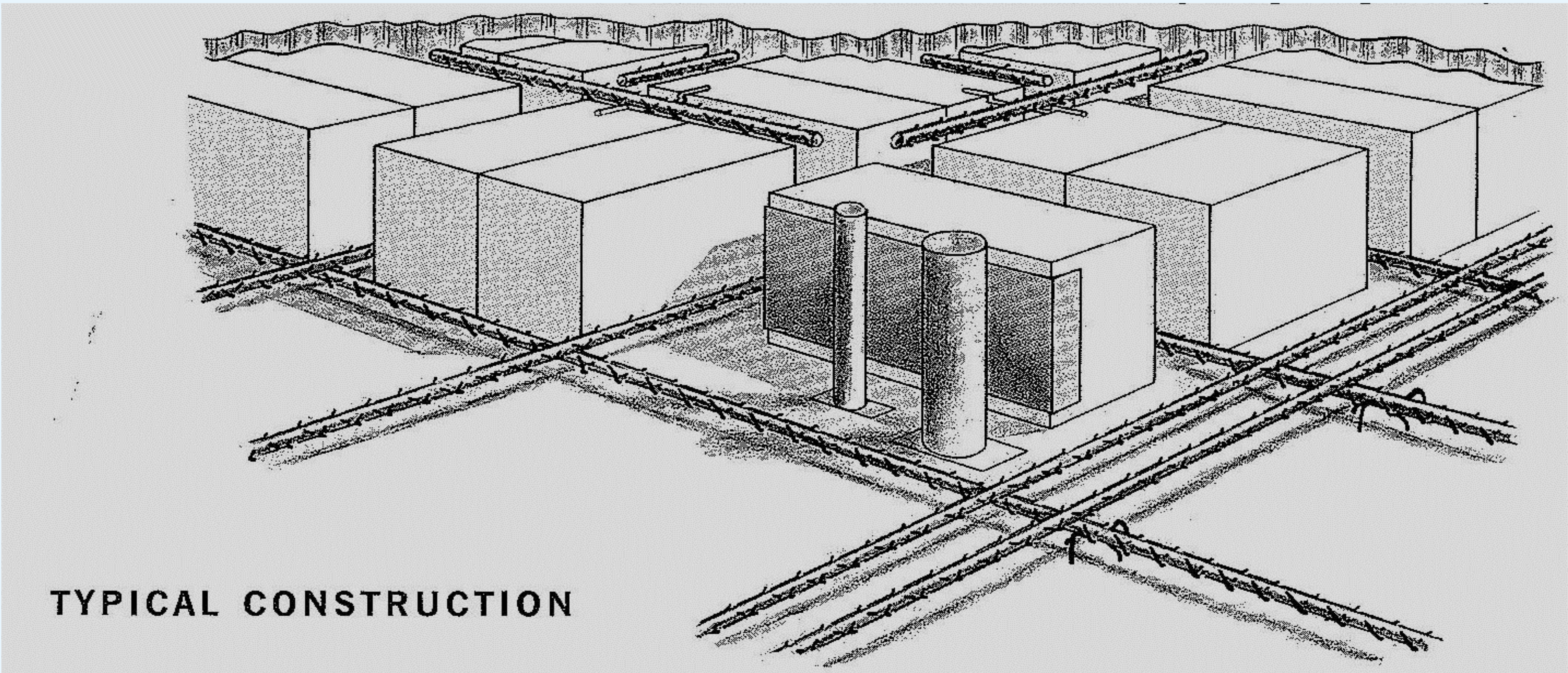




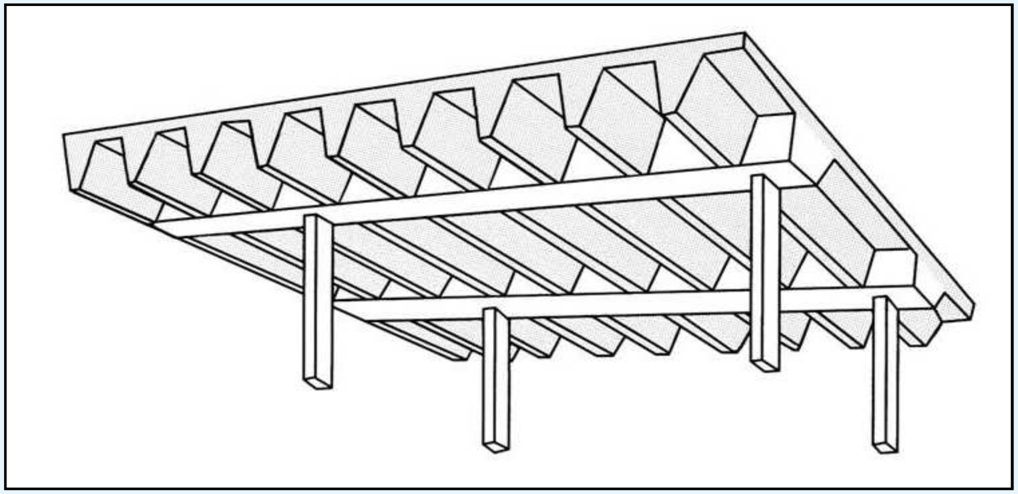
Flat Terra Cotta Arch

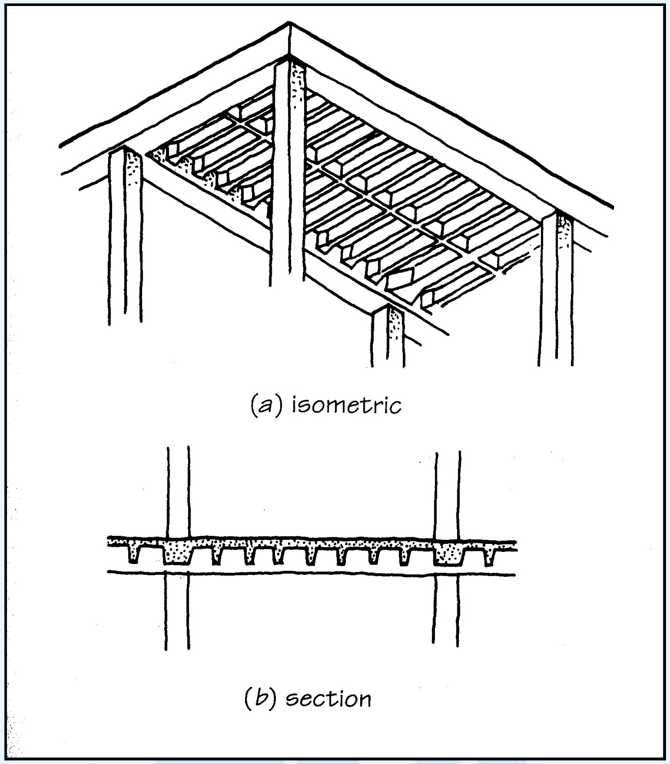


Slag Block

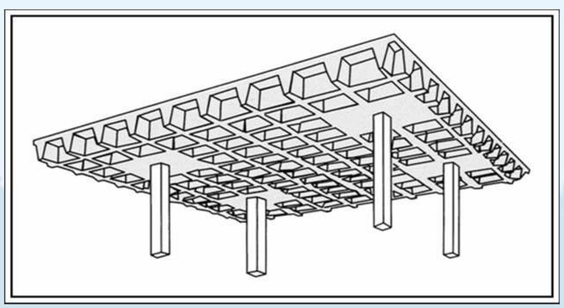


Wide-Module Joists





Waffle Slabs



Hollow Core Plank

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Foam voided Systems

Questions?

CRSI Design Guidelines
Voided Slabs

Attila Beres Ph.D., P.E.

CRSI – Senior Structural Engineering Consultant

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Motivation

To provide guidance to design professionals to introduce an innovative and unconventional system

Associated CRSI publications geared towards contractors:

- Articles in trade publications
- Sample specifications, general notes, typical details etc.

Current Innovation in Void-former Creation




Crate type voids




Tubes

Plastic Balls

Reviewers/Collaborators

Purveyors of Systems/Designers

- Michael Russillo, Christian Roggenbuck (Cobiax)
- Jerry Ames Clark, Dan Windorski (BubbleDeck/Graef)
- Richardo Levinton, Ron Klemencic (Prenova/MKA)

Contractors

- Rocky Bowe (Titan Builders),
- Elan Hertzberg, Dan Stafford (Matt Construction)

Significant Projects Around the World

Millenium Tower
Rotterdam, Netherlands

Airport
Yerevan, Armenia

Palazzo Lombardia
Milan, Italy

Content of Guidelines

- Introduction of Voided Slab Concept
- Historical Overview
- Construction Issues
- Design Regulations
- Design Tools (Tables and Charts)
- Featured Projects
- References

Construction Methods

Why to address constructability in a “Design Guideline”?

- The design means and methods make this system unique
- GCs and Subcontractors are viewing any new systems with skepticism – Who is taking the risk?
- Constructability issues essential to understand to develop design
- For any novel systems the designer is “promoting” the system

Construction Methods

Understanding building methodology:

- Securing void formers against buoyancy
- Sequencing/placement of rebar, void formers, and concrete

Construction Methods

Understanding implications of procedures:

- Shoring, Forming
- Placement of rebar, void formers, and concrete

Where are the $s?

Construction Methods

Addressing constructability concerns:

- Are there any concrete consolidation issues?
- Is there any concern with the interface of 2 concrete lifts?
- Resiliency of void formers at the construction site (handling+ building site foot traffic)?
- Field repositioning
- Time to completion

Construction Methods

Detailing concerns:

- Post-installed anchors
- Intentional drilling into void formers
- Transition between voided areas and solid zones
- Interconnectivity of precast components
- Accommodation of electrical, mechanical, PT conduits

Construction Methods

Administrative implications:

- Placement/shop drawings
- Specifications
- Inspection issues

Design Regulations

Code Compliance:

- ACI 318
- Other IBC Requirements (fire)

Design Regulations

Compliance with non-mandatory considerations:

- Sustainability
- Vibration
- Sound insulation
- Thermal

Design Concepts and Issues

Steps of the Design Procedure:

1. Defining the computational model and parameters
2. Establish adjustment factors specific to the voided slab system
3. Creation of negative dead load patterns
4. Perform initial analysis
5. Shear analysis to establish solid zones
6. Refine iterations
7. Flexural design

Design Concepts and Issues

Parameters Used in Structural Analyses and Design:

- Stiffness
- Flexural strength
- Shear capacity
- Punching shear

Design Concepts and Issues

Example of Weight Reduction:

(shorter span and light load)

- 10” thick slab
- 5.5” tall x 12 3/8” wide void former
- 1 3/8” spacing
- 0.25 ft^3/ft^2 concrete eliminated
- Self weight reduction from 125 psf to 88 psf **-30%**

Design Concepts and Issues

Example of Weight Reduction:

(longer span and heavy load)

- 21" thick slab
- 16" wide spherical void former
- 1 3/4" spacing
- 0.56 ft^3/ft^2 concrete eliminated
- Self weight reduction from 269 psf to 185 psf **-31%**

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Design Concepts and Issues

Other Engineering Design Considerations:

- Diaphragm performance (in plane shear and flexure)
- Design models (similitude with equivalent 2–way solid slabs, 2-way joists)
- Deflection considerations
- Crack-width considerations

Design Concepts and Issues

Detailing issues:

- Layout in typical scenarios
- Layout for complex geometries (non-rectilinear floorplan, upturn beams, steps, openings/edge conditions

Design Tools

- Preliminary sizing - RC Concept
- Samples of Design Documents:
  - General Notes
  - Typical Details
  - Floor Plan Layouts
  - Specifications


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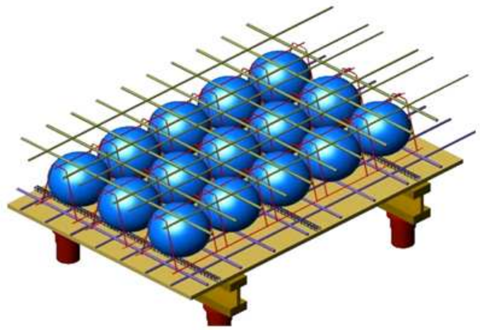
VOIDED SLAB

Economically viable for medium to long spans and for moderate live loads.

Economical Span Range (ft)
Typical slab depths vary from 14" to 24"
Typical "spherical" void-former diameter varies from 9" to 18"



Advantages

- Larger spans without beams
- Larger open floor areas
- Lower floor to floor heights
- Improved Earthquake Performance
- Resource efficency

Click to Close

Placing: 0.00 \$/yd³

Finishing: 0.00 \$/ft²

Curing: 0.00 \$/ft²

Reinforcing in Place:

Rebar: 0.00 \$/ton

Voids in Place: 0.00 \$/ft²

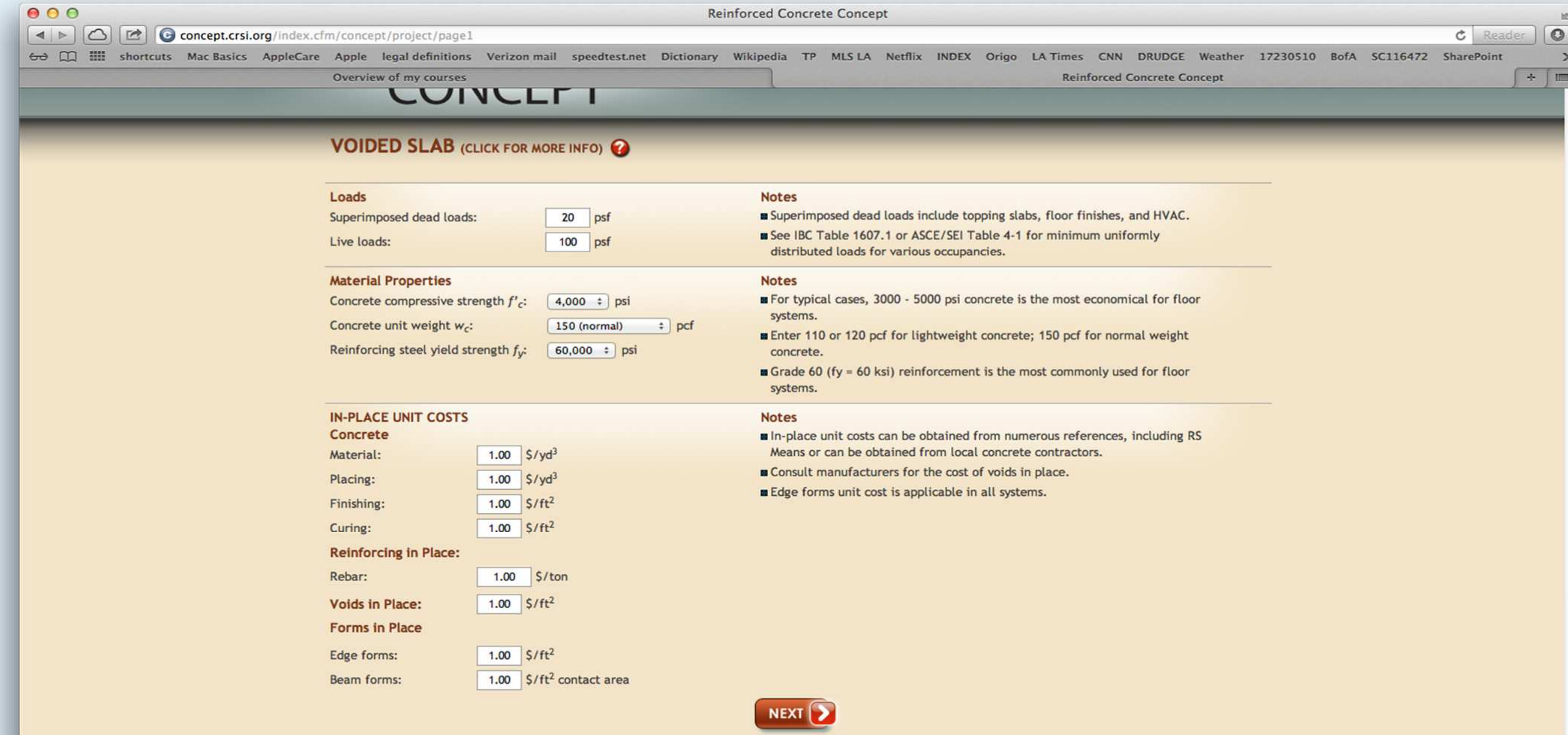
Forms in Place

Edge forms: 0.00 \$/ft²

Beam forms: 0.00 \$/ft² contact area

- Consult manufacturers for the cost of voids in place.
- Edge forms unit cost is applicable in all systems.

RC Concept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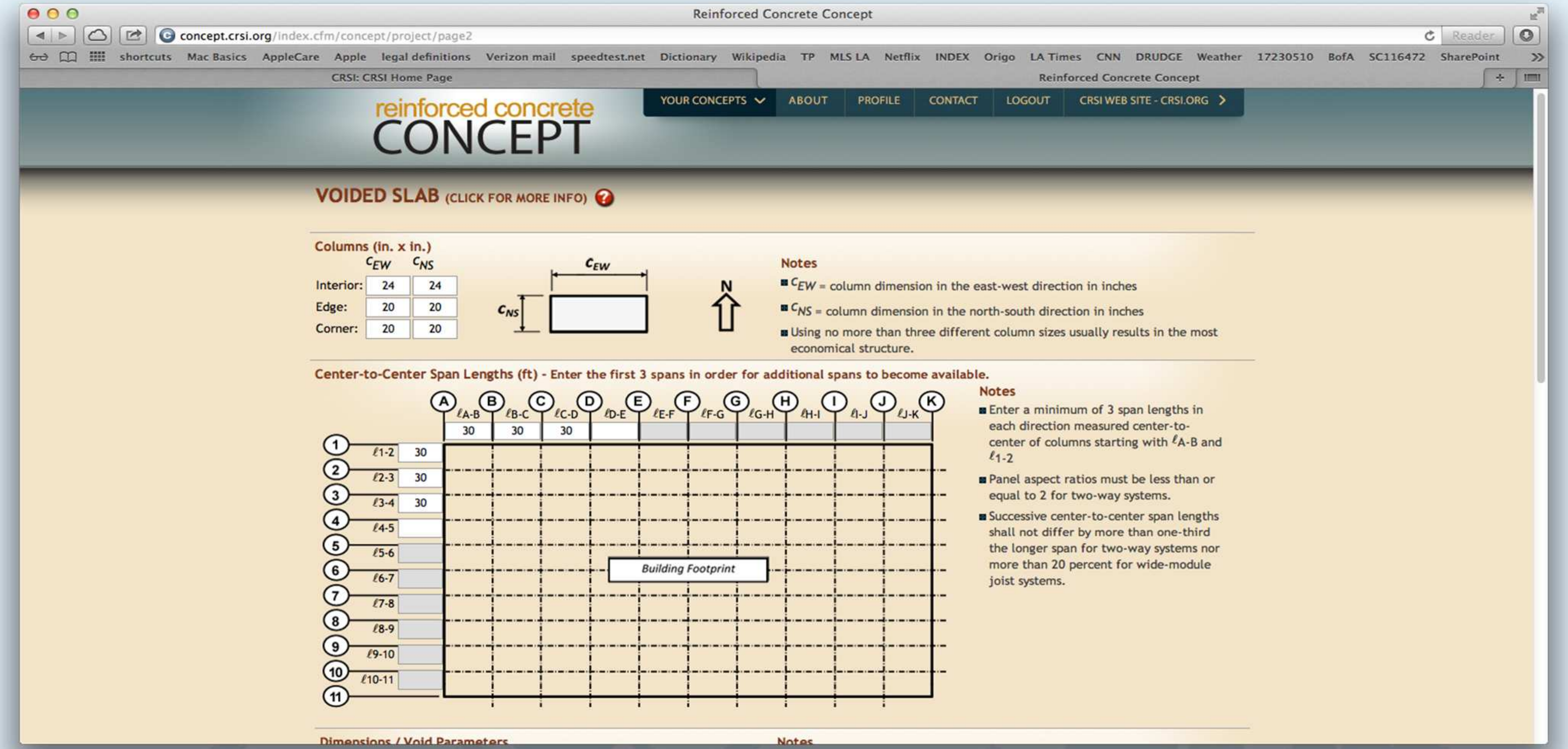
Reinforced Concrete Concept
VOIDED SLAB (CLICK FOR MORE INFO)
Loads
Superimposed dead loads: 20 psf
Live loads: 100 psf
Notes
Superimposed dead loads include topping slabs, floor finishes, and HVAC.
See IBC Table 1607.1 or ASCE/SEI Table 4-1 for minimum uniformly distributed loads for various occupancies.
Material Properties
Concrete compressive strength f'c: 4,000 psi
Concrete unit weight wc: 150 (normal) pcf
Reinforcing steel yield strength fy: 60,000 psi
Notes
For typical cases, 3000 - 5000 psi concrete is the most economical for floor systems.
Enter 110 or 120 pcf for lightweight concrete; 150 pcf for normal weight concrete.
Grade 60 (fy = 60 ksi) reinforcement is the most commonly used for floor systems.
IN-PLACE UNIT COSTS
Concrete
Material: 1.00 $/yd3
Placing: 1.00 $/yd3
Finishing: 1.00 $/ft2
Curing: 1.00 $/ft2
Reinforcing in Place:
Rebar: 1.00 $/ton
Voids in Place: 1.00 $/ft2
Forms in Place
Edge forms: 1.00 $/ft2
Beam forms: 1.00 $/ft2 contact area
Notes
In-place unit costs can be obtained from numerous references, including RS Means or can be obtained from local concrete contractors.
Consult manufacturers for the cost of voids in place.
Edge forms unit cost is applicable in all systems.
NEXT

RC Concept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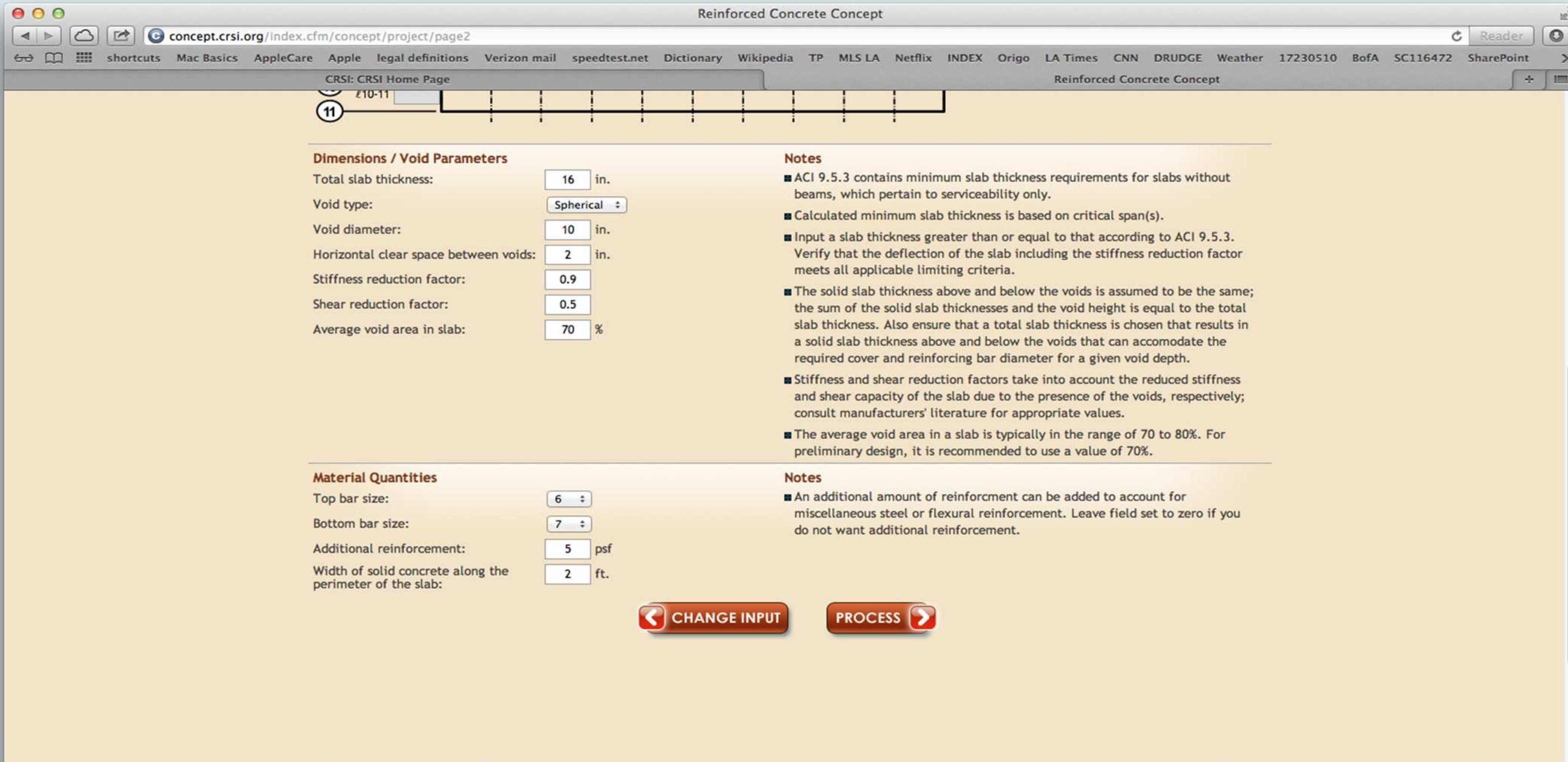
VOIDED SLAB (CLICK FOR MORE INFO)
Columns (in. x in.)
Interior: 24 24
Edge: 20 20
Corner: 20 20
Notes
c_EW = column dimension in the east-west direction in inches
c_NS = column dimension in the north-south direction in inches
Using no more than three different column sizes usually results in the most economical structure.
Center-to-Center Span Lengths (ft) - Enter the first 3 spans in order for additional spans to become available.
Building Footprint
Notes
Enter a minimum of 3 span lengths in each direction measured center-to-center of columns starting with ℓA-B and ℓ1-2
Panel aspect ratios must be less than or equal to 2 for two-way systems.
Successive center-to-center span lengths shall not differ by more than one-third the longer span for two-way systems nor more than 20 percent for wide-module joist systems.

RC Concept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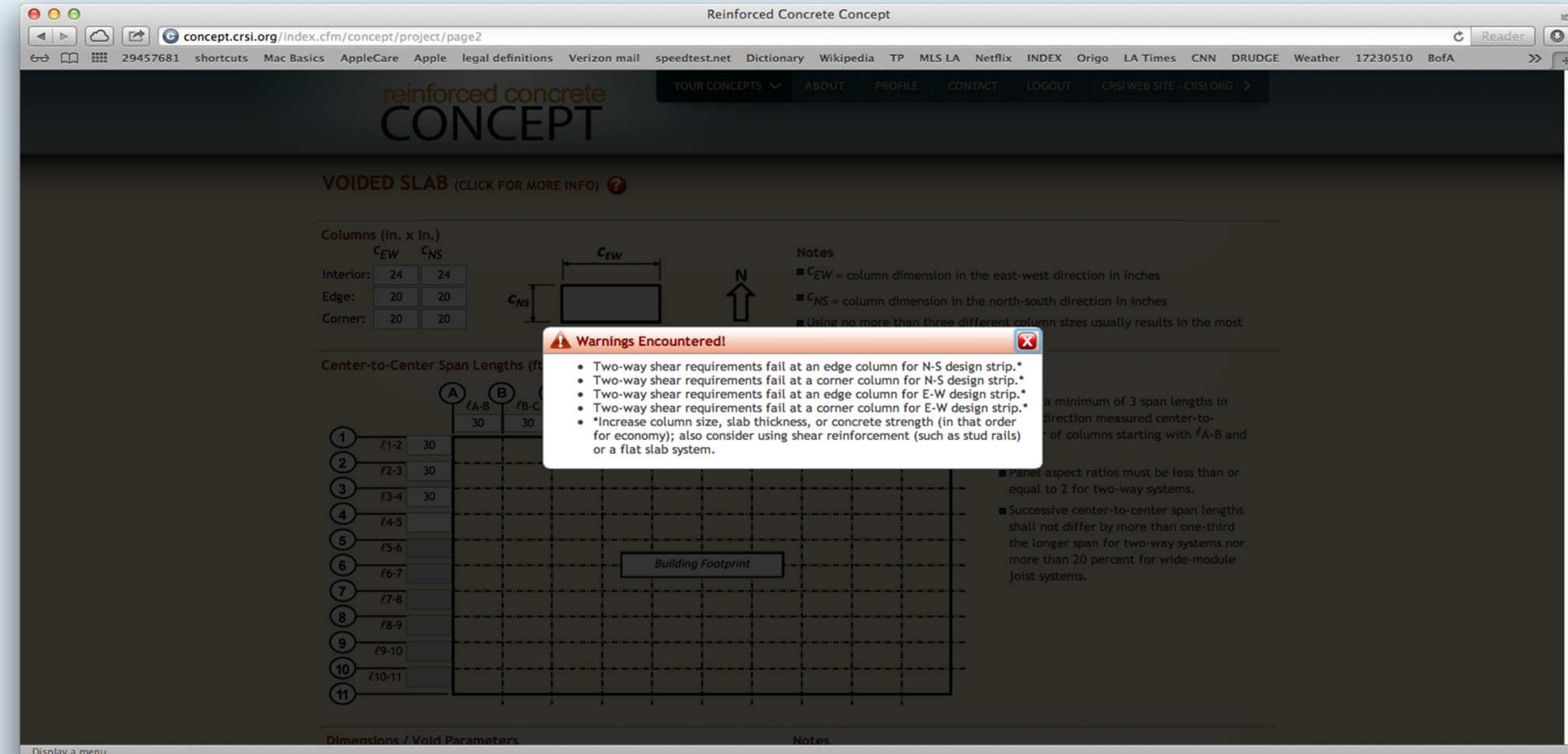
Dimensions / Void Parameters
Total slab thickness: 16 in.
Void type: Spherical
Void diameter: 10 in.
Horizontal clear space between voids: 2 in.
Stiffness reduction factor: 0.9
Shear reduction factor: 0.5
Average void area in slab: 70 %
Notes
ACI 9.5.3 contains minimum slab thickness requirements for slabs without beams, which pertain to serviceability only.
Calculated minimum slab thickness is based on critical span(s).
Input a slab thickness greater than or equal to that according to ACI 9.5.3. Verify that the deflection of the slab including the stiffness reduction factor meets all applicable limiting criteria.
The solid slab thickness above and below the voids is assumed to be the same; the sum of the solid slab thicknesses and the void height is equal to the total slab thickness. Also ensure that a total slab thickness is chosen that results in a solid slab thickness above and below the voids that can accomodate the required cover and reinforcing bar diameter for a given void depth.
Stiffness and shear reduction factors take into account the reduced stiffness and shear capacity of the slab due to the presence of the voids, respectively; consult manufacturers' literature for appropriate values.
The average void area in a slab is typically in the range of 70 to 80%. For preliminary design, it is recommended to use a value of 70%.
Material Quantities
Top bar size: 6
Bottom bar size: 7
Additional reinforcement: 5 psf
Width of solid concrete along the perimeter of the slab: 2 ft.
Notes
An additional amount of reinforcment can be added to account for miscellaneous steel or flexural reinforcement. Leave field set to zero if you do not want additional reinforcement.
CHANGE INPUT
PROCESS

RC Concept



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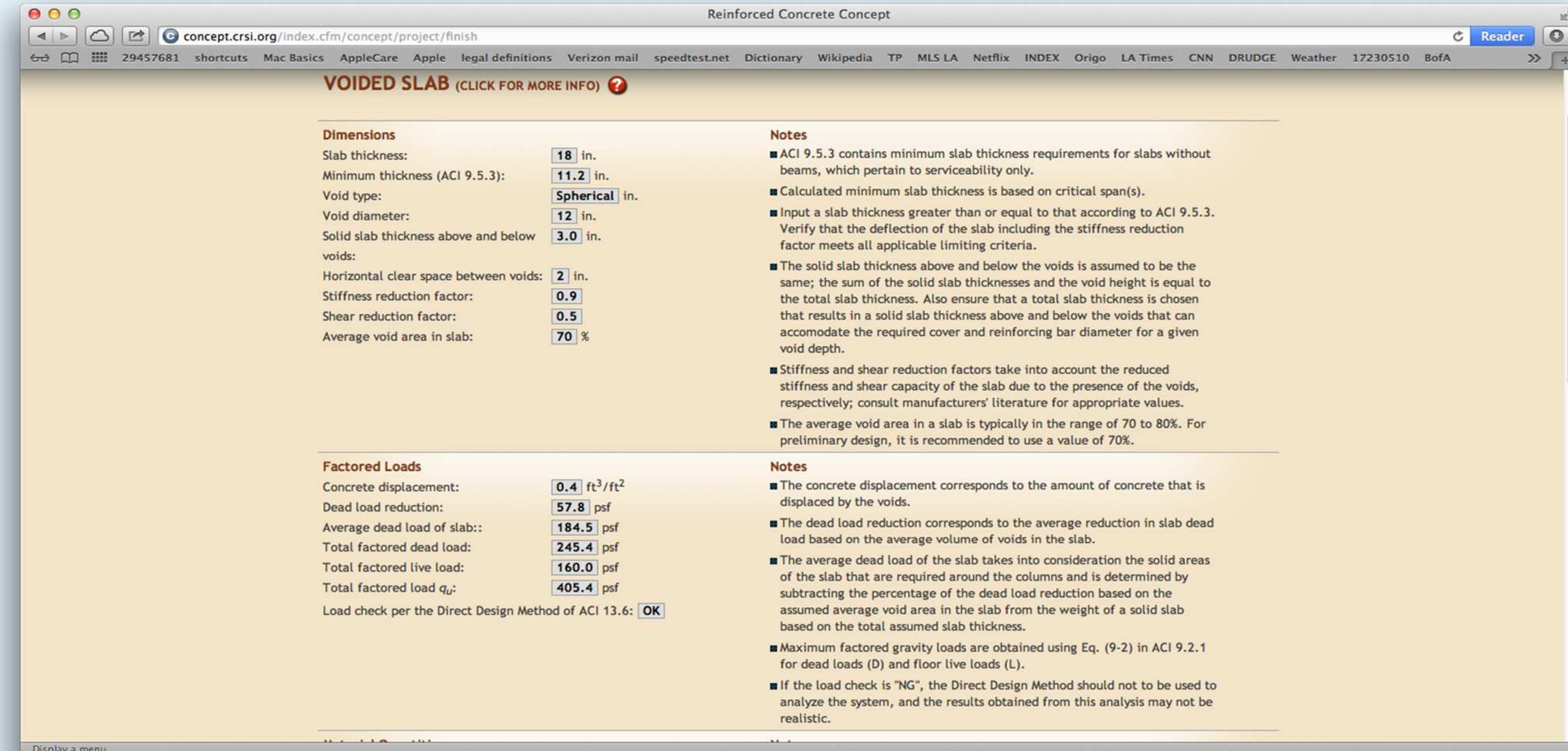
reinforced concrete
CONCEPT
VOIDED SLAB (CLICK FOR MORE INFO)
Columns (in. x in.)
Interior: 24 24
Edge: 20 20
Corner: 20 20
Notes
Warnings Encountered!
• Two-way shear requirements fail at an edge column for N-S design strip.*
• Two-way shear requirements fail at a corner column for N-S design strip.*
• Two-way shear requirements fail at an edge column for E-W design strip.*
• Two-way shear requirements fail at a corner column for E-W design strip.*
• *Increase column size, slab thickness, or concrete strength (in that order for economy); also consider using shear reinforcement (such as stud rails) or a flat slab system.
Building Footprint

RC Concept



Reinforced Concrete Concept

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VOIDED SLAB (CLICK FOR MORE INFO)

Dimensions

Slab thickness:	18 in.
Minimum thickness (ACI 9.5.3):	11.2 in.
Void type:	Spherical in.
Void diameter:	12 in.
Solid slab thickness above and below voids:	3.0 in.
Horizontal clear space between voids:	2 in.
Stiffness reduction factor:	0.9
Shear reduction factor:	0.5
Average void area in slab:	70 %

Notes

- ACI 9.5.3 contains minimum slab thickness requirements for slabs without beams, which pertain to serviceability only.
- Calculated minimum slab thickness is based on critical span(s).
- Input a slab thickness greater than or equal to that according to ACI 9.5.3. Verify that the deflection of the slab including the stiffness reduction factor meets all applicable limiting criteria.
- The solid slab thickness above and below the voids is assumed to be the same; the sum of the solid slab thicknesses and the void height is equal to the total slab thickness. Also ensure that a total slab thickness is chosen that results in a solid slab thickness above and below the voids that can accomodate the required cover and reinforcing bar diameter for a given void depth.
- Stiffness and shear reduction factors take into account the reduced stiffness and shear capacity of the slab due to the presence of the voids, respectively; consult manufacturers' literature for appropriate values.
- The average void area in a slab is typically in the range of 70 to 80%. For preliminary design, it is recommended to use a value of 70%.

Factored Loads

Concrete displacement:	0.4 ft^3/ft^2
Dead load reduction:	57.8 psf
Average dead load of slab::	184.5 psf
Total factored dead load:	245.4 psf
Total factored live load:	160.0 psf
Total factored load q_u:	405.4 psf
Load check per the Direct Design Method of ACI 13.6:	OK

Notes

- The concrete displacement corresponds to the amount of concrete that is displaced by the voids.
- The dead load reduction corresponds to the average reduction in slab dead load based on the average volume of voids in the slab.
- The average dead load of the slab takes into consideration the solid areas of the slab that are required around the columns and is determined by subtracting the percentage of the dead load reduction based on the assumed average void area in the slab from the weight of a solid slab based on the total assumed slab thickness.
- Maximum factored gravity loads are obtained using Eq. (9-2) in ACI 9.2.1 for dead loads (D) and floor live loads (L).
- If the load check is "NG", the Direct Design Method should not to be used to analyze the system, and the results obtained from this analysis may not be realistic.

Display a menu

RC Concept

Reinforced Concrete Concept

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Material Quantities

Top bar size:	6	
Width of solid concrete along the perimeter of the slab:	3	ft.
Bottom Bar Size:	7	
Concrete:	1.22	(ft^3/ft^2)
Minimum required area of solid concrete around each column:		
Corner:	9.00	(ft^2)
Edge:	67.00	(ft^2)
Interior:	262.00	(ft^2)
Reinforcement:	4.27	psf
Additional Reinforcement:	5	psf
Total reinforcement:	9.27	psf
Formwork:	1.00	(ft^3/ft^2)
Number of voids:	0.74	($1/ft^2$)
Void area in slab:	71.58	%

Notes

- For puposes of preliminary design, a program limitation is that the neutral axis must fall within the soild slab portion above or below the voids; a warning message is generated if the neutral axis falls within the void region.
- The width of solid concrete around the perimeter of the slab is usually 2 feet, but should not be taken less than 1 foot.
- An additional amount of reinforcement can be added to account for miscellaneous steel or flexural reinforcement.
- The required area of solid concrete around each column is determined using the shear reduction factor. The lower bound for this area is determined assuming that there is one row of voids placed around the perimeter of each column.
- It is recommended to leave out at least one row of voids along openings in the slabs even if the allowable shear force for the voided slab is not exceeded in these areas.
- The percent of void area in the slab, which is equal to the area of the slab that contains voids divided by the total area, is calculated using the minimum required area of solid concrete around each column and the width of solid concrete along the perimeter of the slab. The analysis can be refined by inputting this value for the average void area in slab.

COSTS

Concrete

Material:	0.05	$/ft^2	
Placing:	0.05	$/ft^2	
Finishing:	1.00	$/ft^2	
Curing:	1.00	$/ft^2	
Total concrete:	2.10	$/ft^2	20.71 %

Reinforcing in Place:	0.00	$/ft^2	0.00 %
Voids in Place	1.00	$/ft^2	9.86 %
Forms in Place			
Flat forms:	7.00	$/ft^2	
Edge forms:	0.04	$/ft^2	
Total forms:	7.04	$/ft^2	69.43 %

TOTAL COST: 10.14 $/ft^2

Processing Time: 12 sec

CHANGE INPUT FINISH

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New Trends - Case Studies:

Miami Art Museum
UW LaBahn Arena
Harvey Mudd College

Miami Art Museum
Construction Progress Report

ACI 421 Session on Innovative Slab Design

VOIDED SLAB TECHNOLOGY
OPTIMIZING DESIGN AND IMPROVING CONSTRUCTABILITY

Michael A. Russillo, President
Cobiax USA Inc.
April 14, 2013

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- Brief description of voided slab technology
- How the concept is implemented
- Sequence of construction
- Special features
- Concrete facts and project credits
- Questions ?

Twin Cities
Spring 2013
Responsibility in Concrete Construction

Perez Art Museum Miami (PAMM)

- **Opening: Fall 2013**
- **4 levels: Interior 120,000sf; exterior 80,000sf**
- **6 void sizes covering 80,000 sf**
- **Exposed Concrete w/ Architectural finishes**
- **Voided Slab Drivers:**
  - **Large spans with flat soffit**
  - **Thick slabs due to 4” and 6” rebates**
  - **2” cover for slab reinforcing**
  - **Reduction of weight on piles**
  - **Silver LEED Certification**

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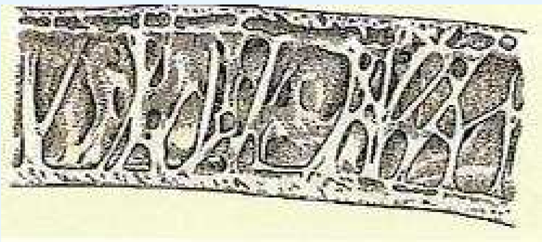
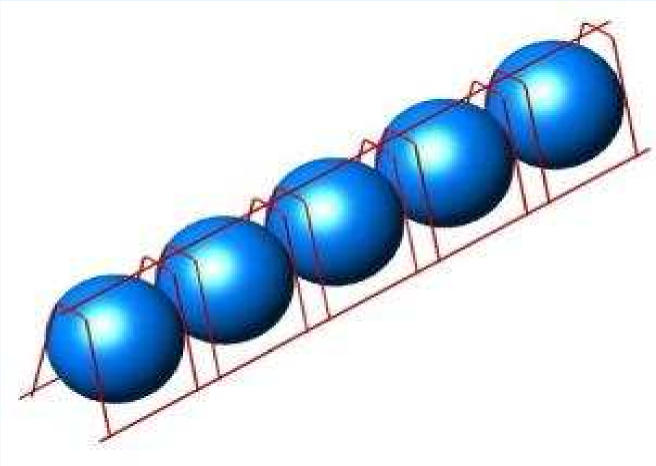
Basic idea of the voided slab technology



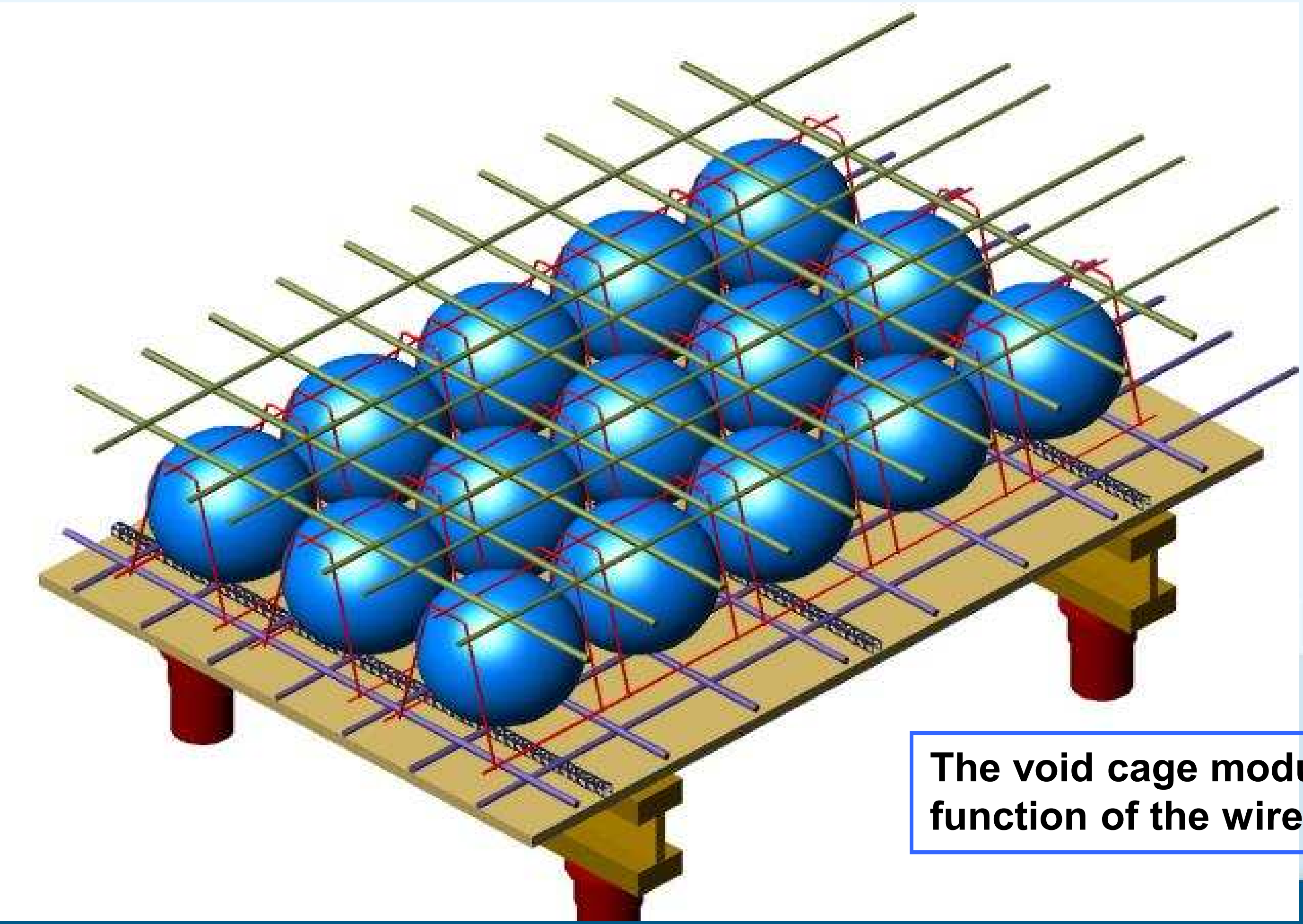
Eliminate concrete in the zones of a slab where from a static perspective there is no necessity for it. At the same time, optimize the slab's thickness and building material volume.

Implementation of the idea



Hollow voids of recycled plastic, positioned in appropriate zones of flat plate slabs, contribute to dead load reduction without modifying flexural strength and load transfer to supports.

Mounting of cobiax in an in-situ slab



→ Top static reinforcement

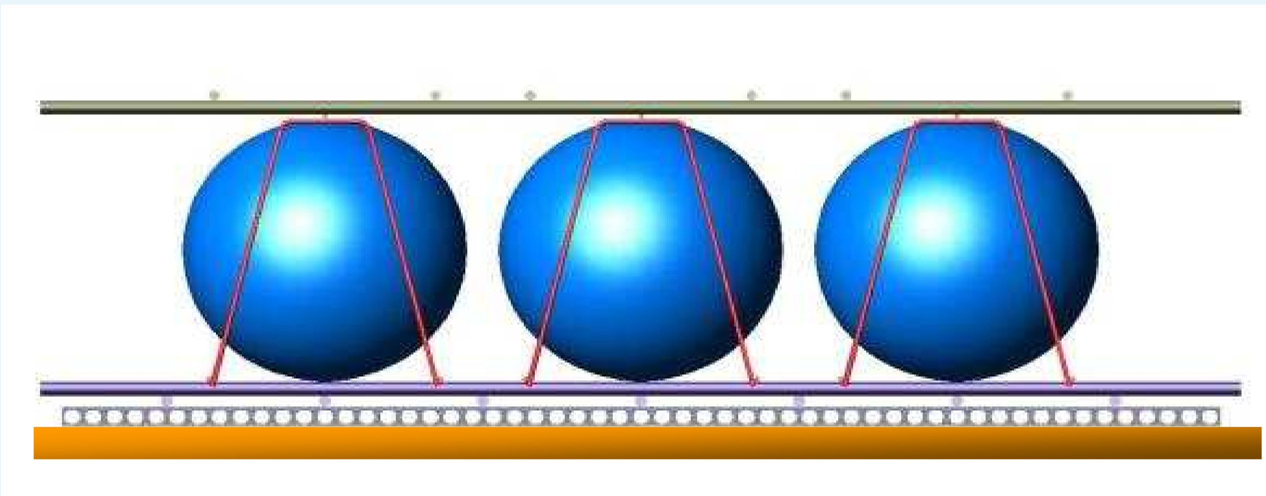
→ **void cage modules**

→ Bottom static reinforcement

→ Formwork & bracing

The void cage modules take over the function of the wire chairs

Cross section with voids (in-situ slab)



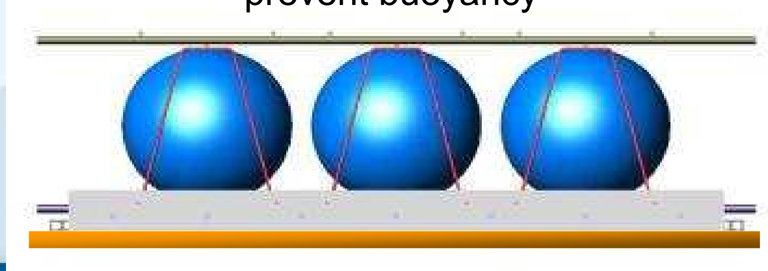
→ Top static reinforcement

→ **void cage modules**

→ Bottom static reinforcement

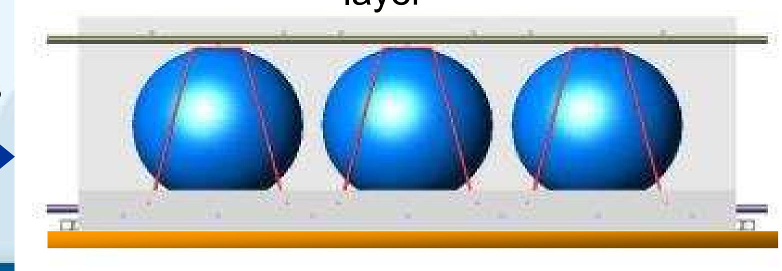
→ Formwork & bracing

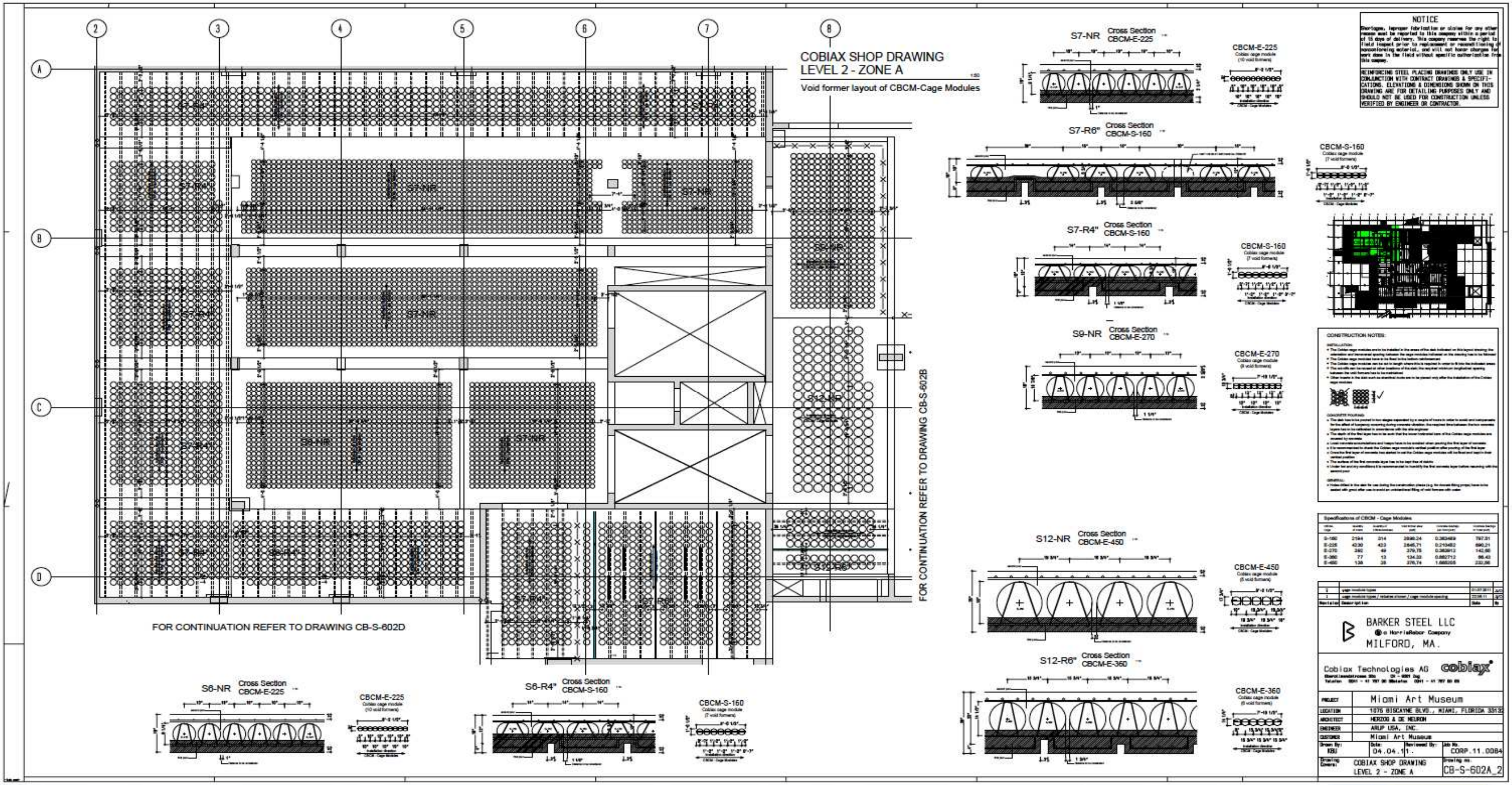
1st concreting stage: Anchorage layer to prevent buoyancy



x hours

2nd concreting stage: Remaining concrete after initial setting of 1st layer





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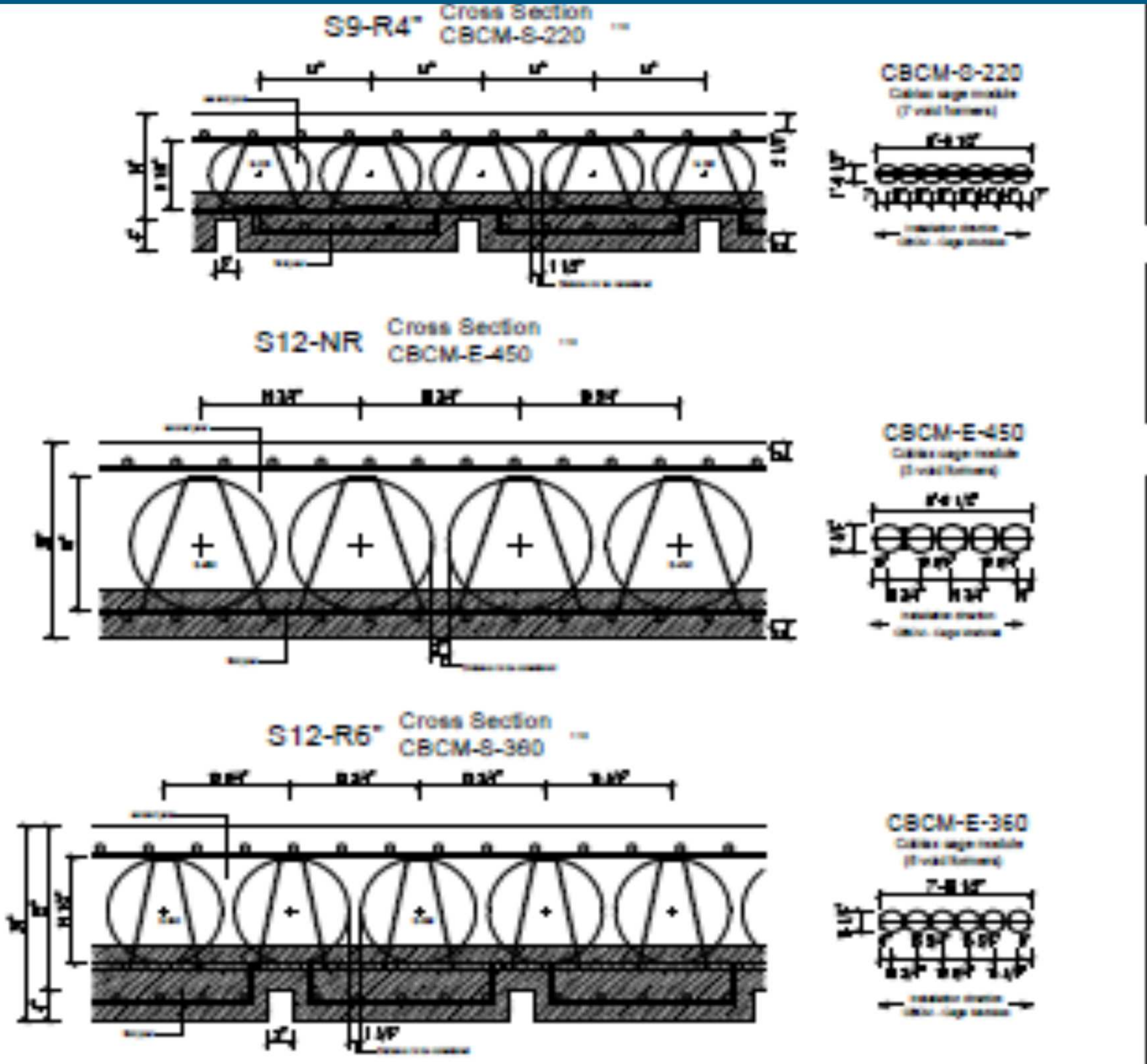

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VOID CAGE STORAGE ON SITE

Sunrise on Biscayne Bay….

……More Voids to Install

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Installing & Spacing Voids

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450 mm voids


04/17/2012


04/19/2012

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Clean-out before the
concrete placement


ULTRA
03/05/2012

Twin Cities Spring 2013 Responsibility in Concrete Construction

Mockup

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MAM Mockup:
Exposed Ceiling / Rebates / Textured Wall

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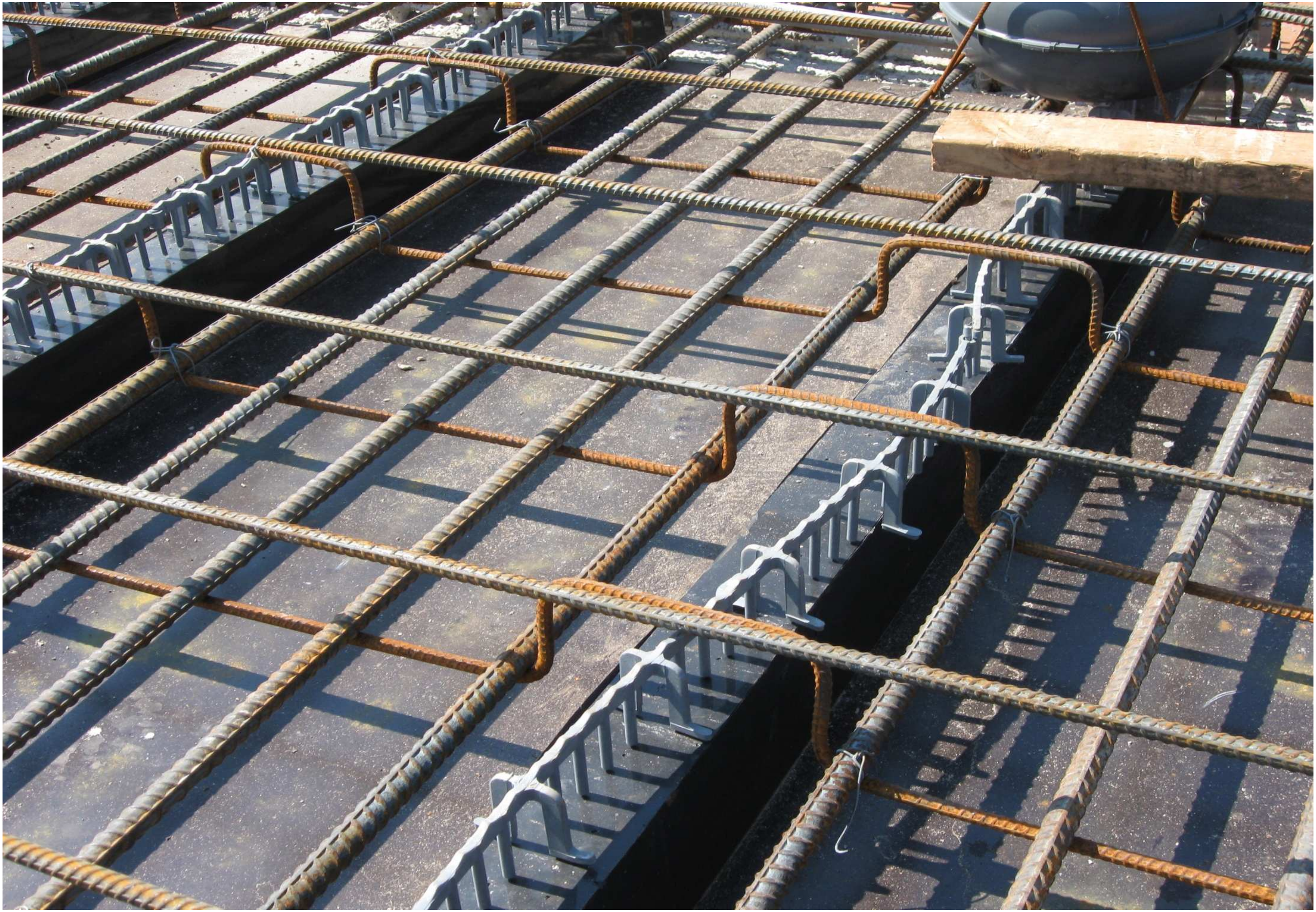
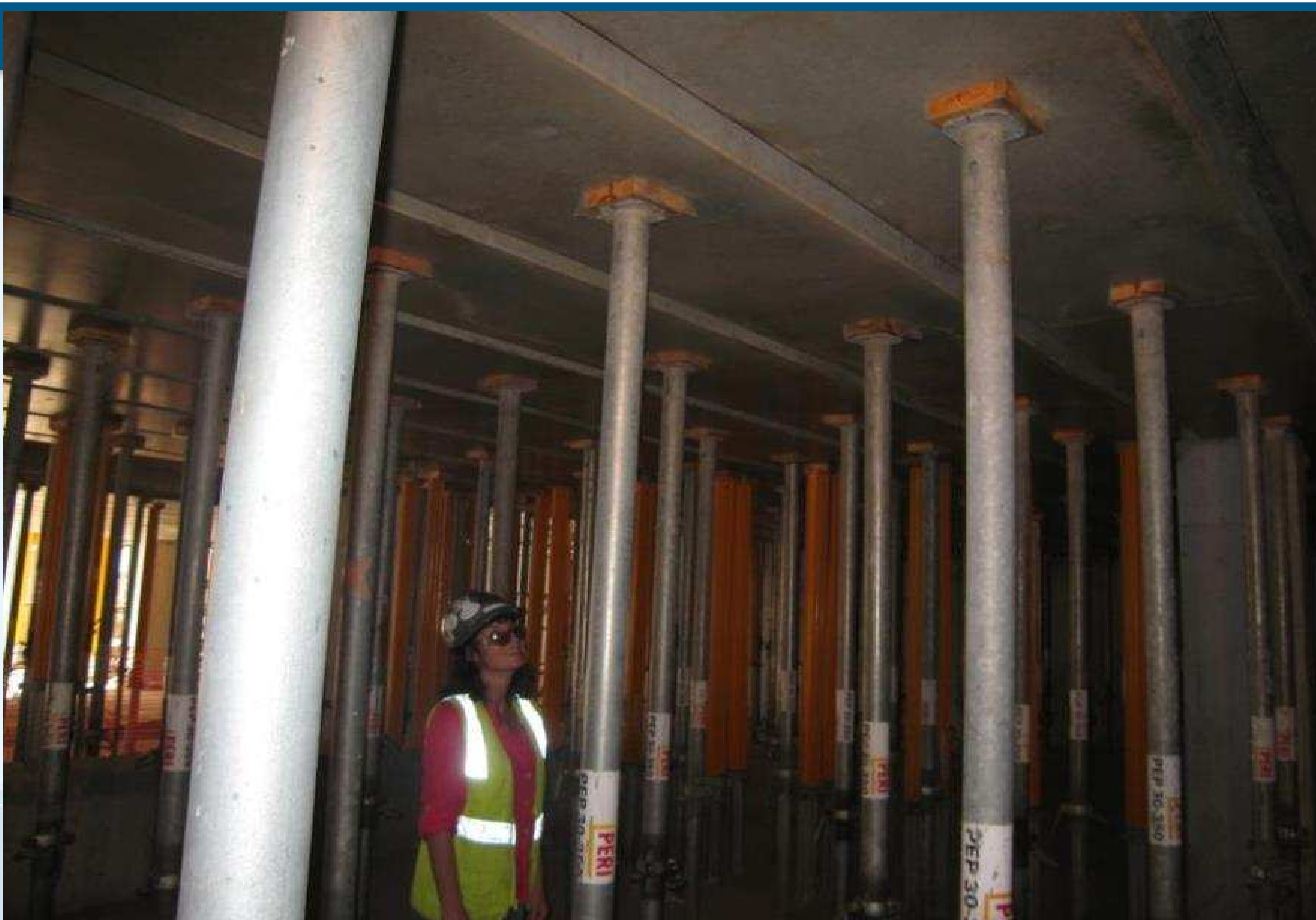
09/11/2012


09/11/2012


09/11/2012





Reshore of Exposed Ceiling

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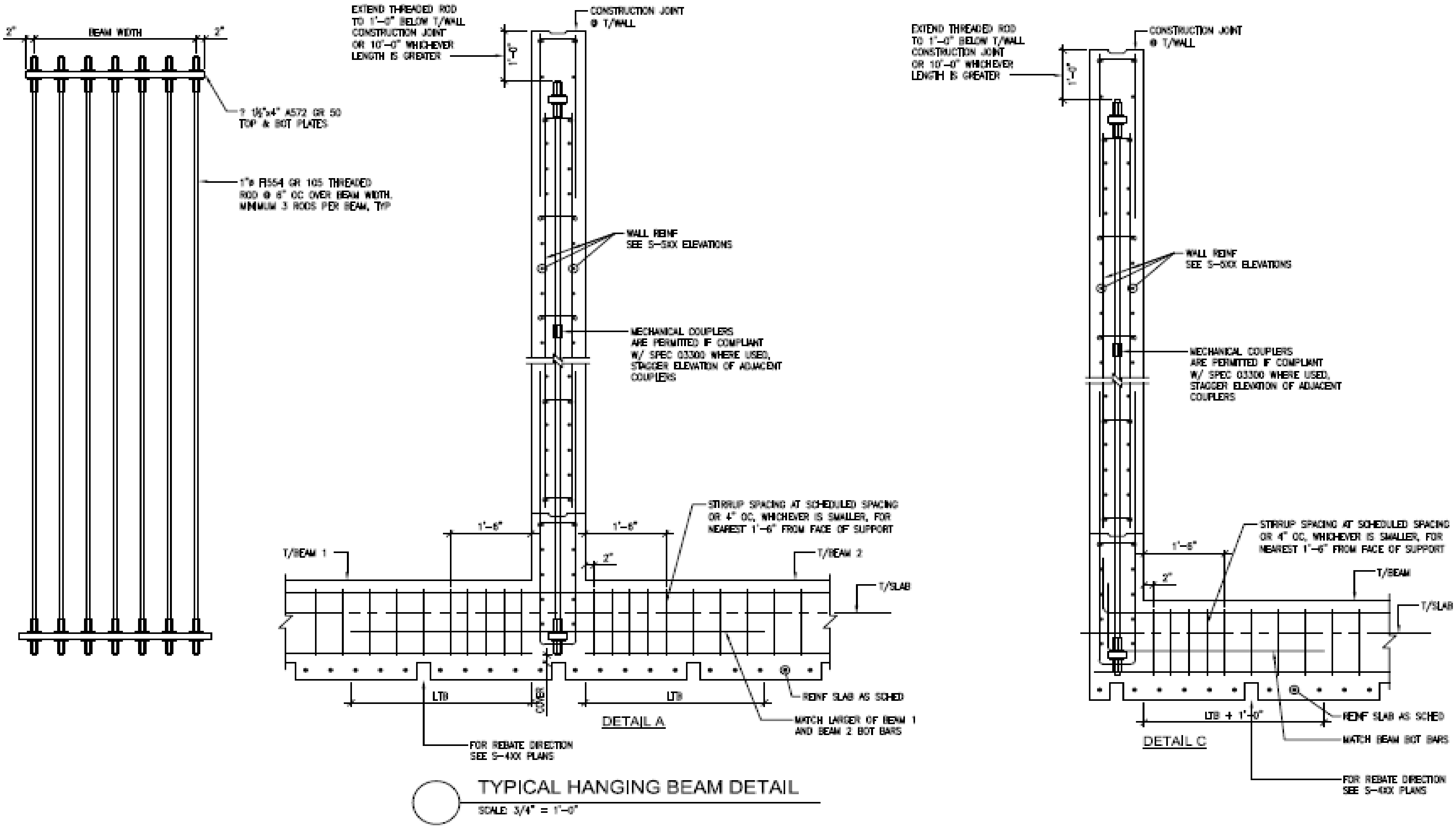
Exposed ceiling w/ 4” & 6” rebates

Upturned Beam


AIRMAN


2"
BEAM WIDTH
2"
? 1¼"x4" A572 GR 50 TOP & BOT PLATES
1"ø F1554 GR 105 THREADED ROD @ 6" OC OVER BEAM WIDTH, MINIMUM 3 RODS PER BEAM, TYP
EXTEND THREADED ROD TO 1'-0" BELOW T/WALL CONSTRUCTION JOINT OR 10'-0" WHICHEVER LENGTH IS GREATER
1'-0"
CONSTRUCTION JOINT @ T/WALL
WALL REINF SEE S-5XX ELEVATIONS
MECHANICAL COUPLERS ARE PERMITTED IF COMPLIANT W/ SPEC 03300 WHERE USED, STAGGER ELEVATION OF ADJACENT COUPLERS
STIRRUP SPACING AT SCHEDULED SPACING OR 4" OC, WHICHEVER IS SMALLER, FOR NEAREST 1'-6" FROM FACE OF SUPPORT
1'-6"
1'-6"
2"
T/BEAM 1
T/BEAM 2
T/SLAB
LTB
COVER
LTB
REINF SLAB AS SCHED
MATCH LARGER OF BEAM 1 AND BEAM 2 BOT BARS
FOR REBATE DIRECTION SEE S-4XX PLANS
DETAIL A
TYPICAL HANGING BEAM DETAIL
SCALE: 3/4" = 1'-0"
T/BEAM
LTB + 1'-0"
MATCH BEAM BOT BARS
DETAIL C

Sloped Auditorium Slab

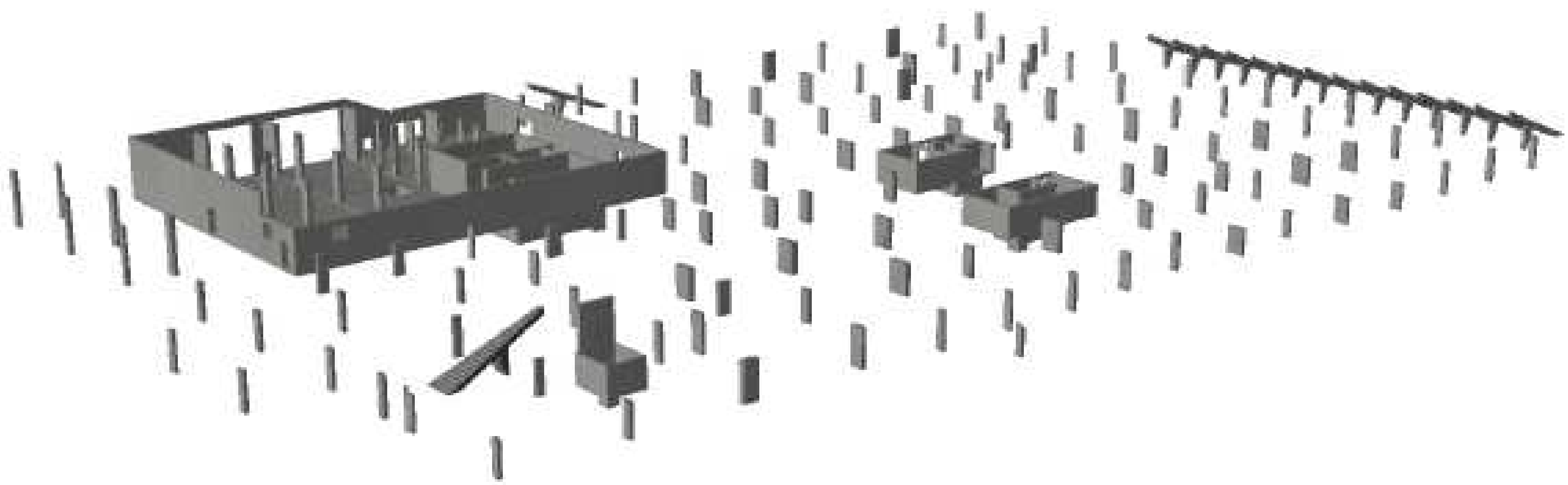

EXPOSED BEAMS

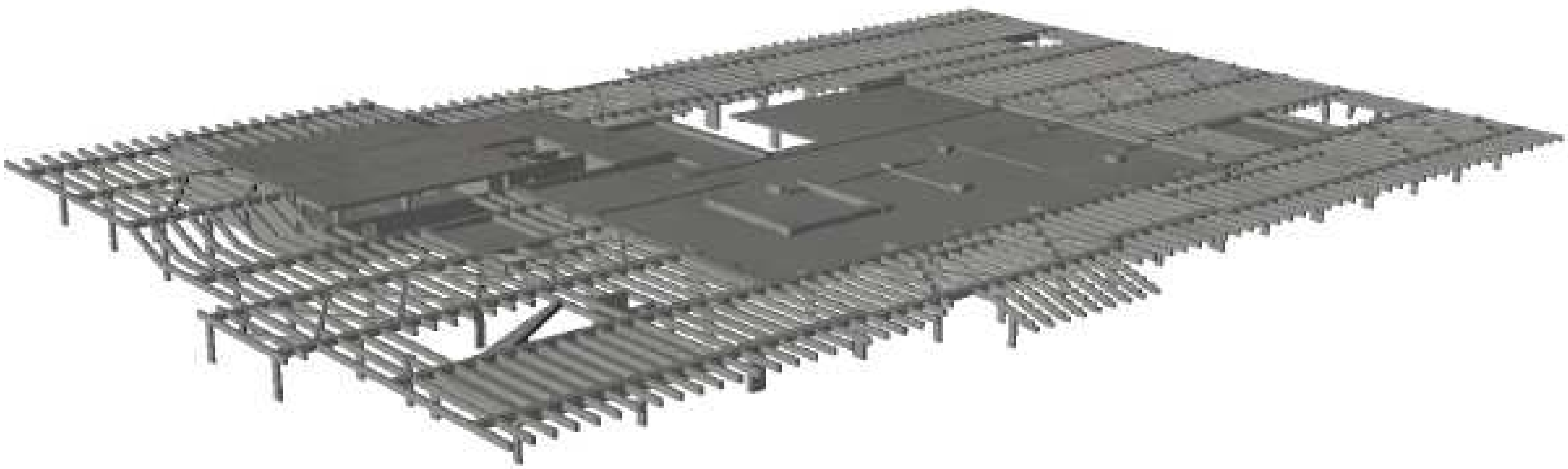

PERI

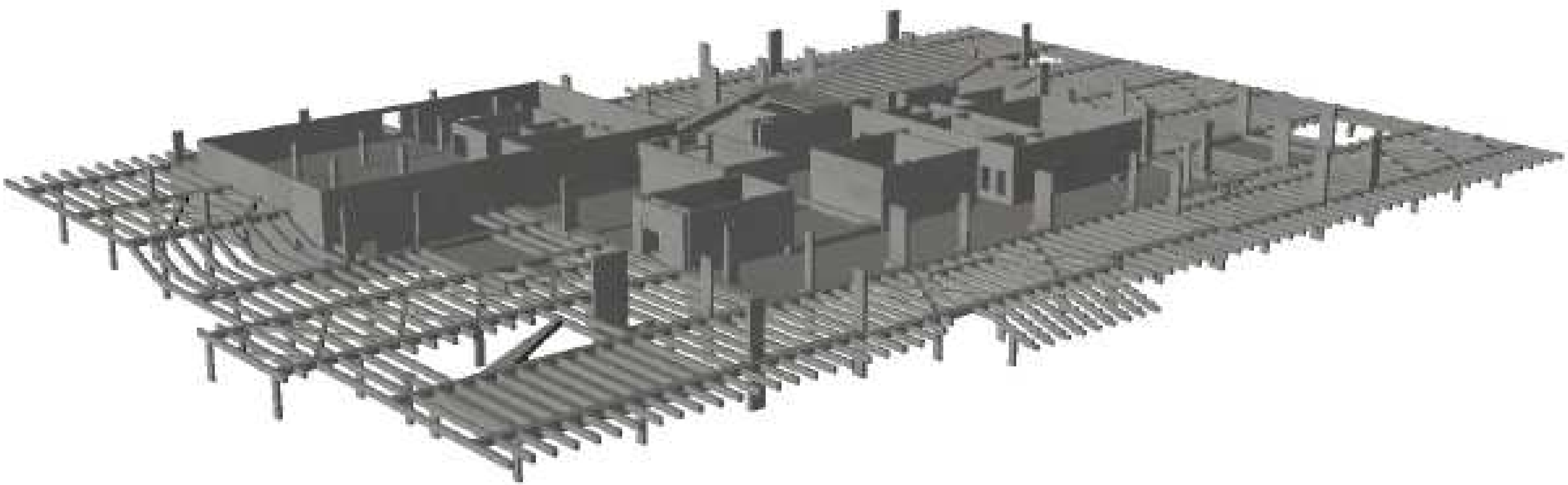
Flying in Rebar for a Wall

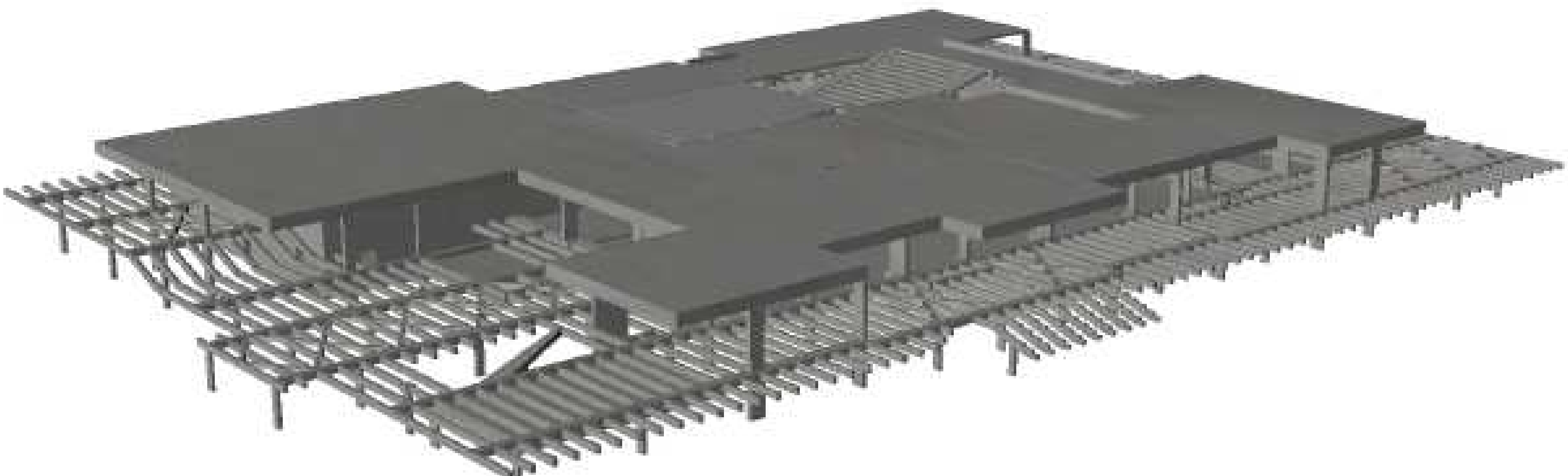

RWP
RWP

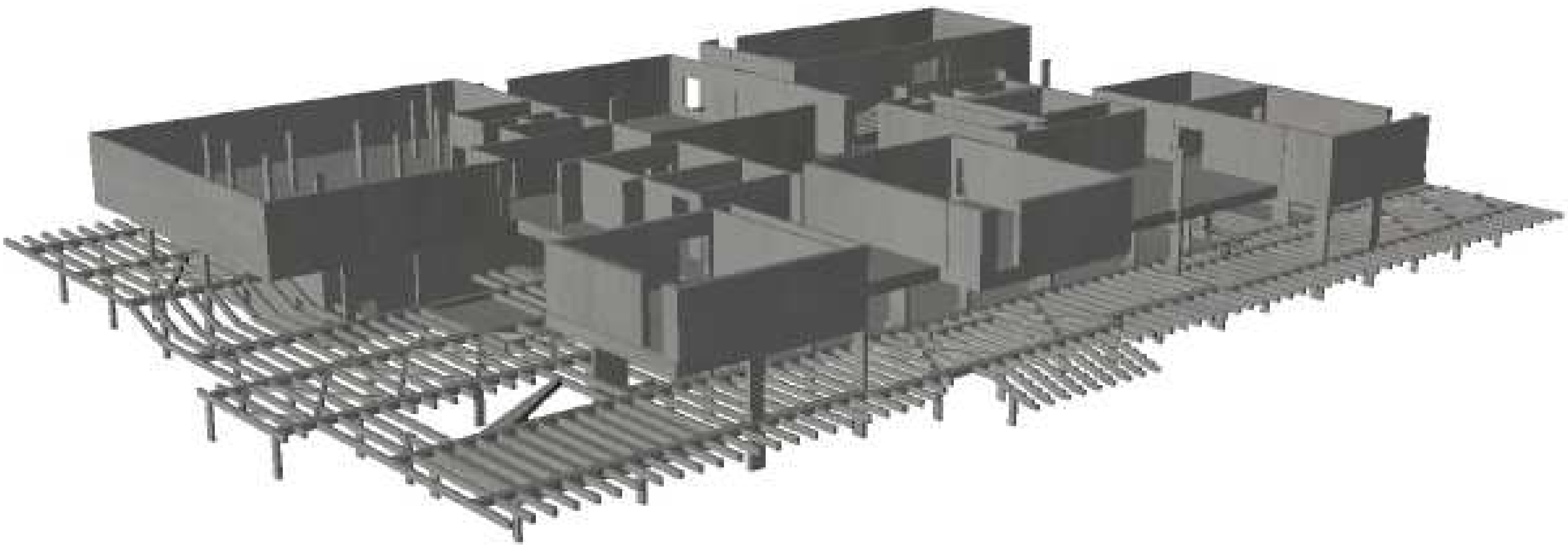
CONSTRUCTION SEQUENCE

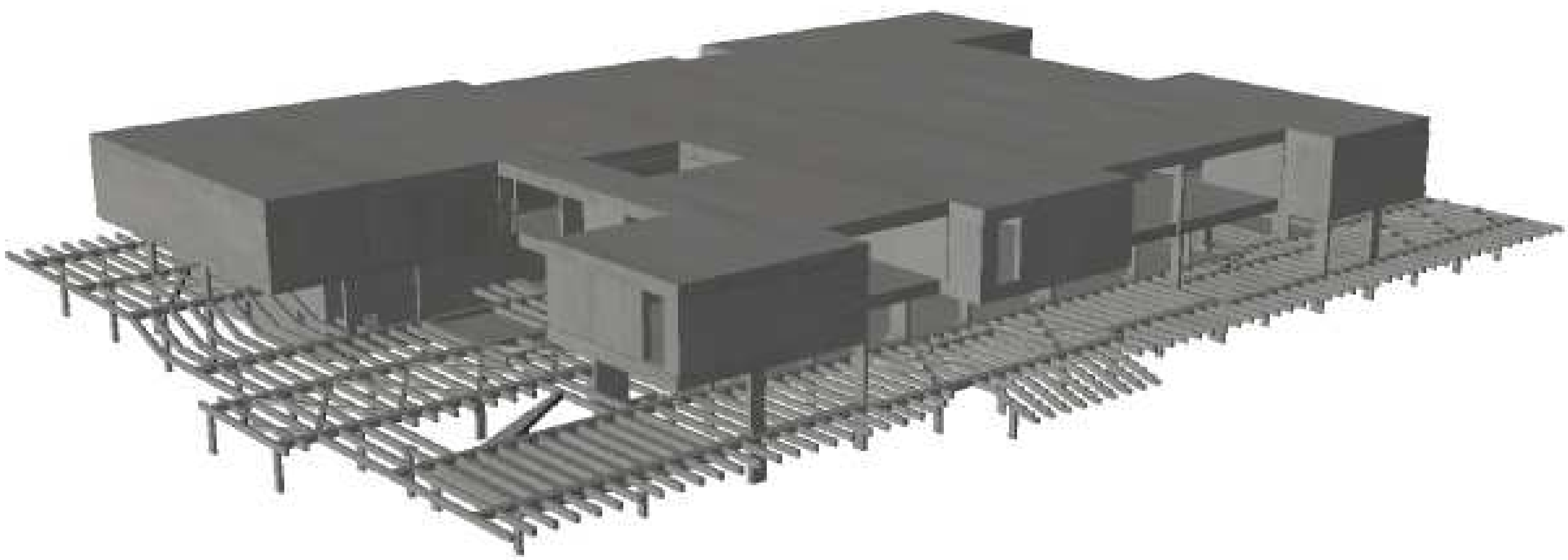


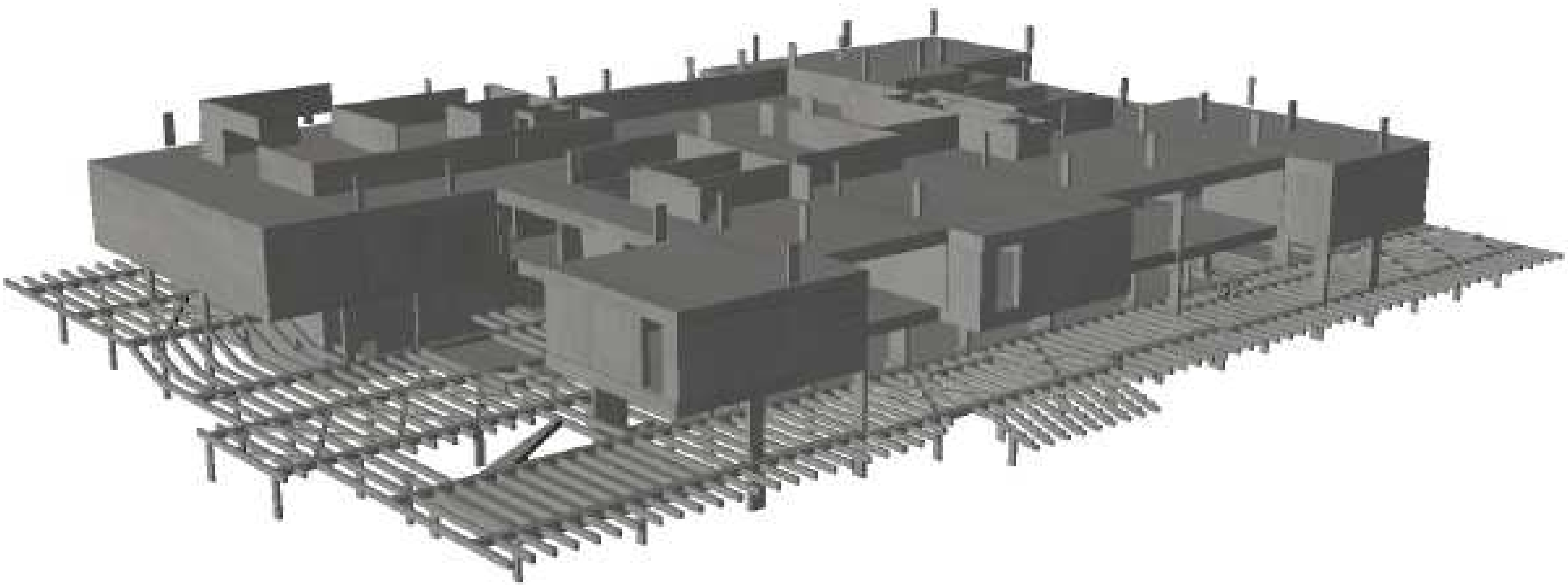


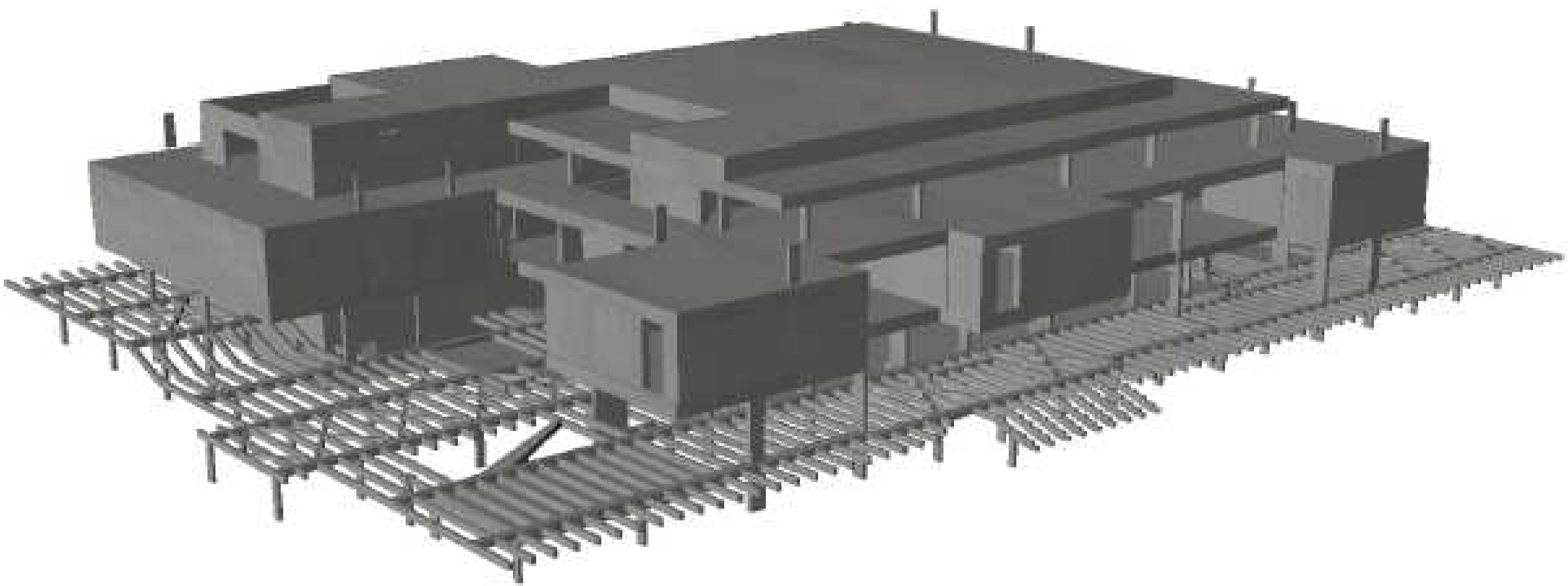


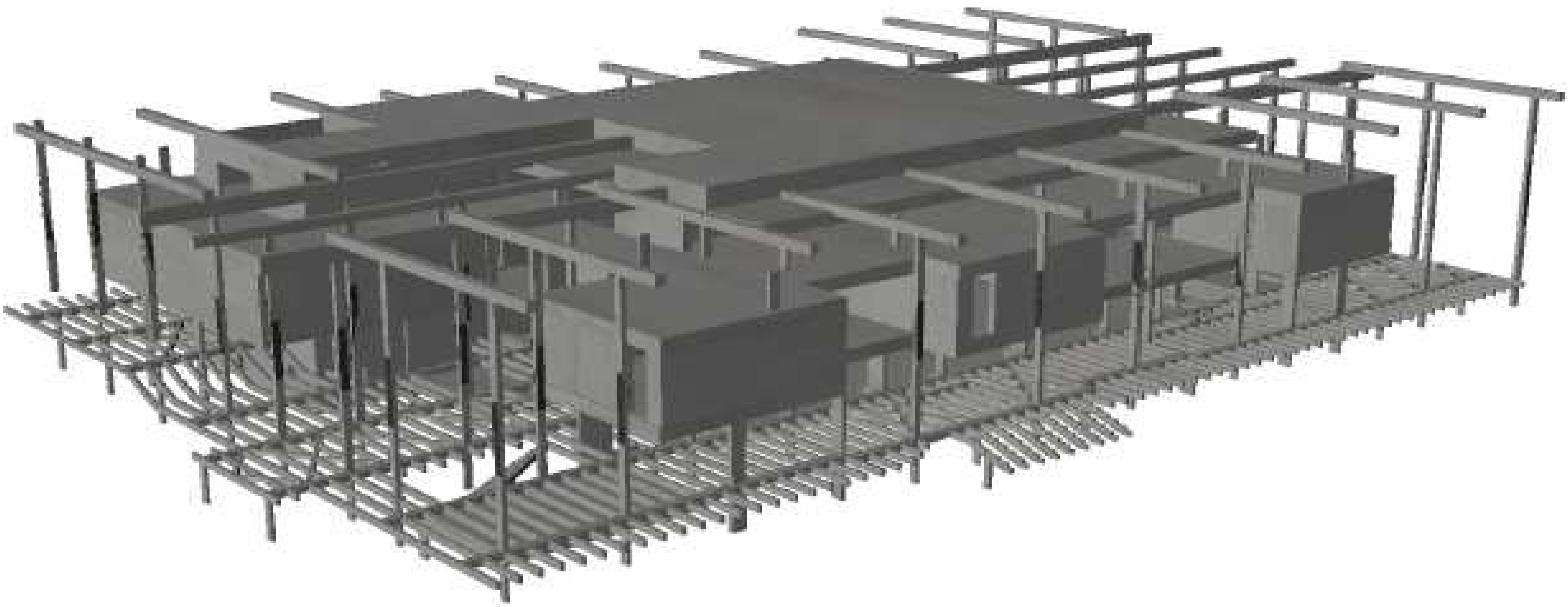


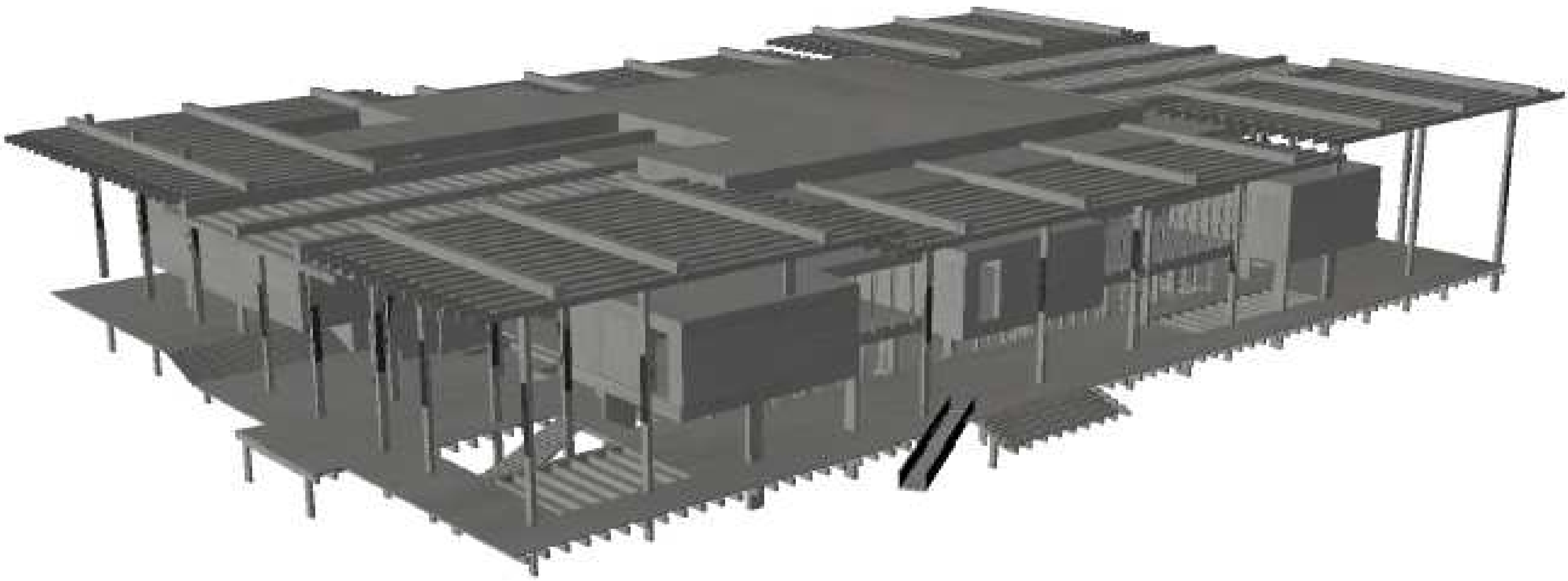


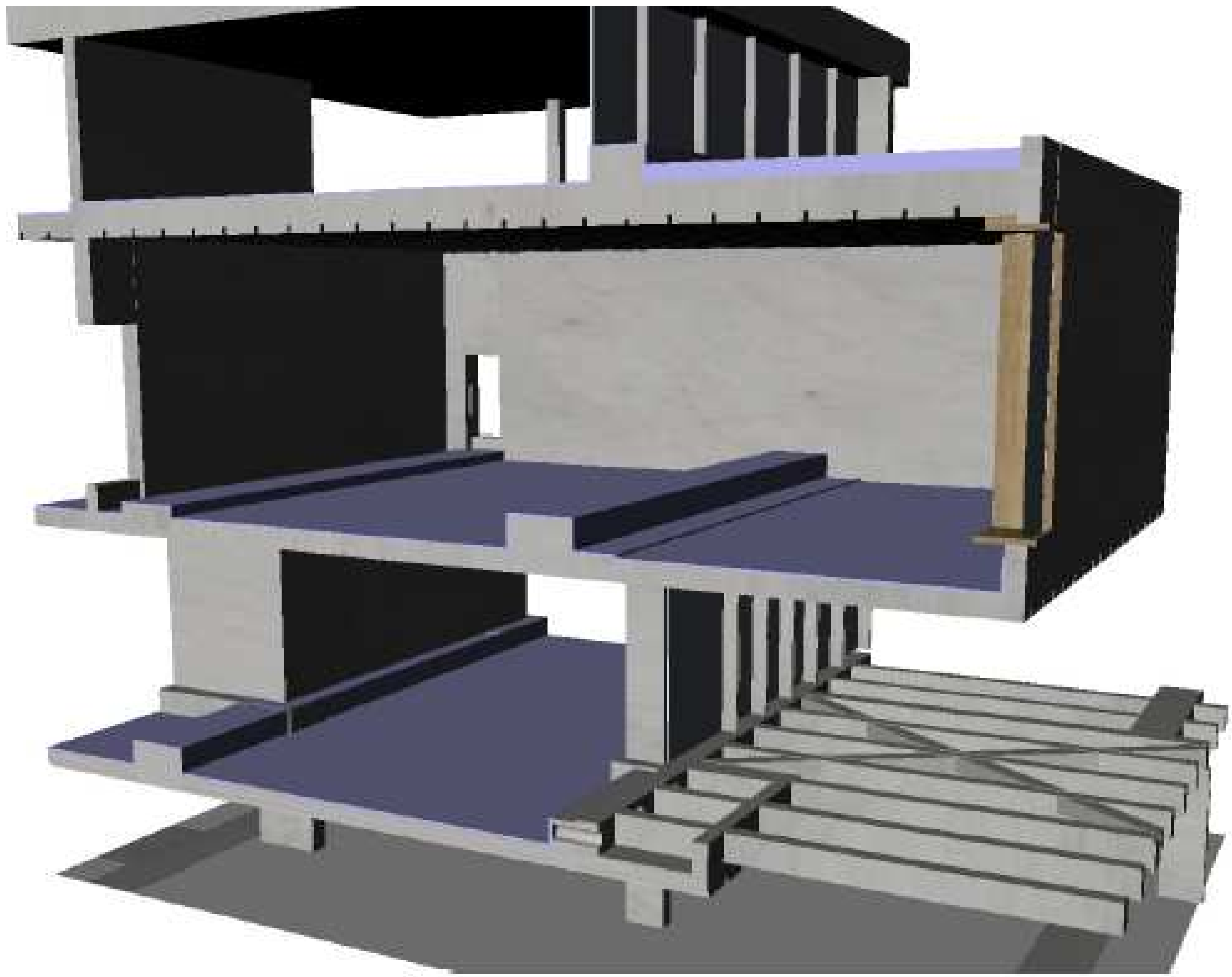


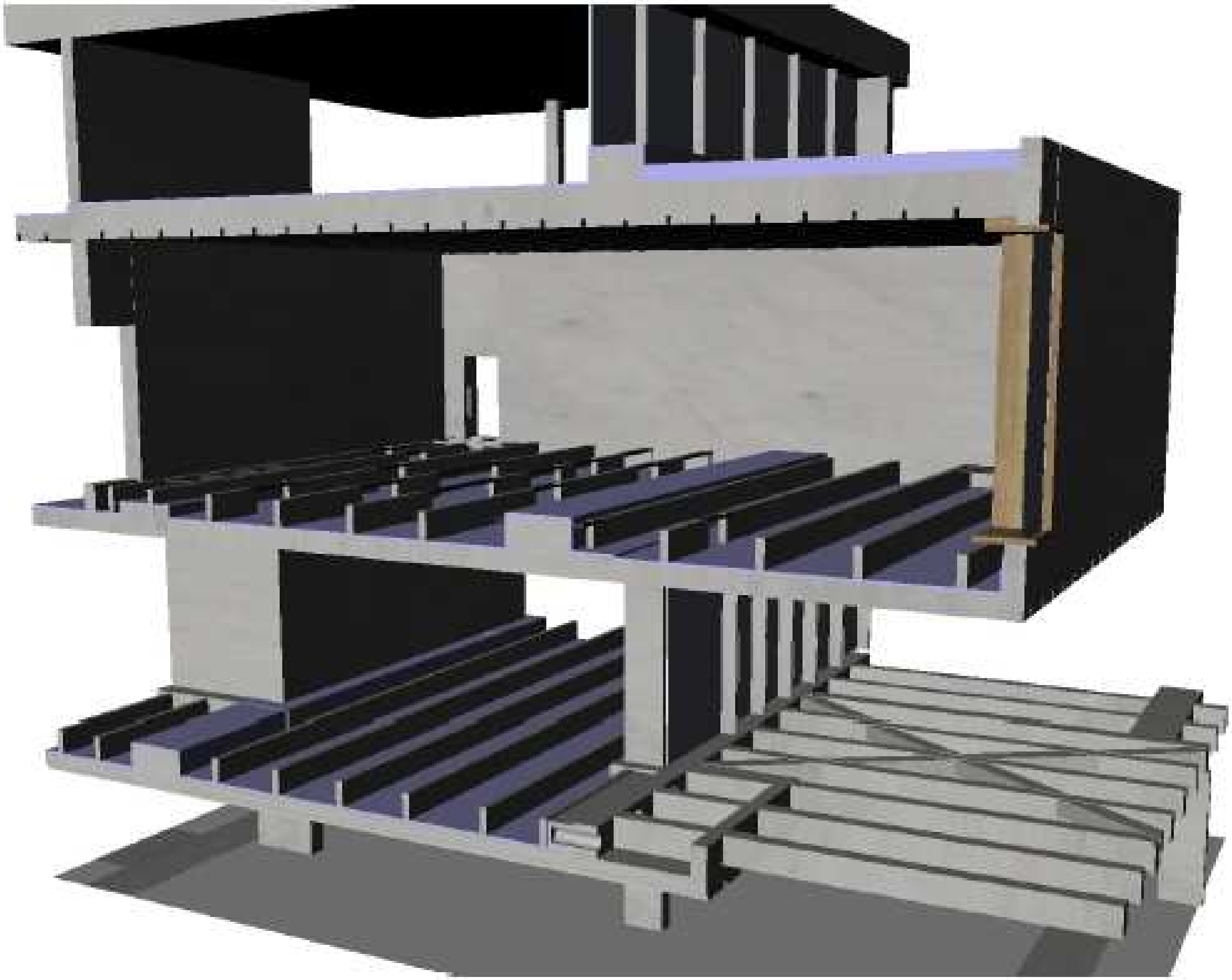













MORIARTY

Twin Cities
aci
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Responsibility
in Concrete Construction

MIAMI ART MUSEUM Significant numbers

- GROSS AREA: 200,000 sf: 120,000 interior + 80,000 exterior
- TOTAL CONCRETE YARDAGE: 17,500 CY; 6,000 psi

  Supplier: Tarmac Concrete (Titan America)
- TOTAL REBAR TONNAGE: 3,000 tons

  Supplier: Gancedo Rebar Services
- VOIDS COVERED AREA: 80,000 sf
- 6 VOID SIZES: S-180, S-220, E-225, E-270, E-360 & E-450
- VOLUME OF CONCRETE DISPLACED: 935 CY
- WEIGHT REDUCTION ON PILES: 1,750 tons

MIAMI ART MUSEUM Formwork and Concrete info

- Slab forms : ¾" sacrificial deck/back-up (MDO plywood) to minimize deflection with 5'x10' sheets of either Riga or Finn Form on top for form finish.
- Wall forms of Finn Maxi-Ply on good side, backed with ¾" plyform also to minimize deflection.
- Rebates were formed with beveled 4x4 fir in 10' lengths, faced with 5/8" Exactu.
- Cover: 2" for slabs; 2-1/2" for beams and columns
- Slag used to lighten w/ a blend of pea rock and regular rock. 5,000 psi specified / 6,000 psi delivered
- Shrinkage reducing admixtures used in most of the concrete.

Perez Art Museum Miami (PAMM)

Project Director: Paratus Group, NY, NY

Design Consultant: Herzog & de Meuron, Basel, Switzerland

Executive Architect: Handel Architects, NY, NY

Structural Engineer & M/E Engineer: Arup, NY, NY

Construction Manager: John Moriarty & Assoc., Florida

Concrete Contractor:

Baker Concrete / Reinforced Structures Inc., JV

Reinforcing & Cobiax Supply and Installation:

Titon Builders Inc.

Perez Art Museum Miami (PAMM)

Twin Cities Spring 2013 Responsibility in Concrete Construction

THANK YOU !

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Dedham, MA 02026 mrussillo@cobiaxusa.com
Tel: (781) 381-0111 Internet: www.cobiaxusa.com

Precast Voided Slabs

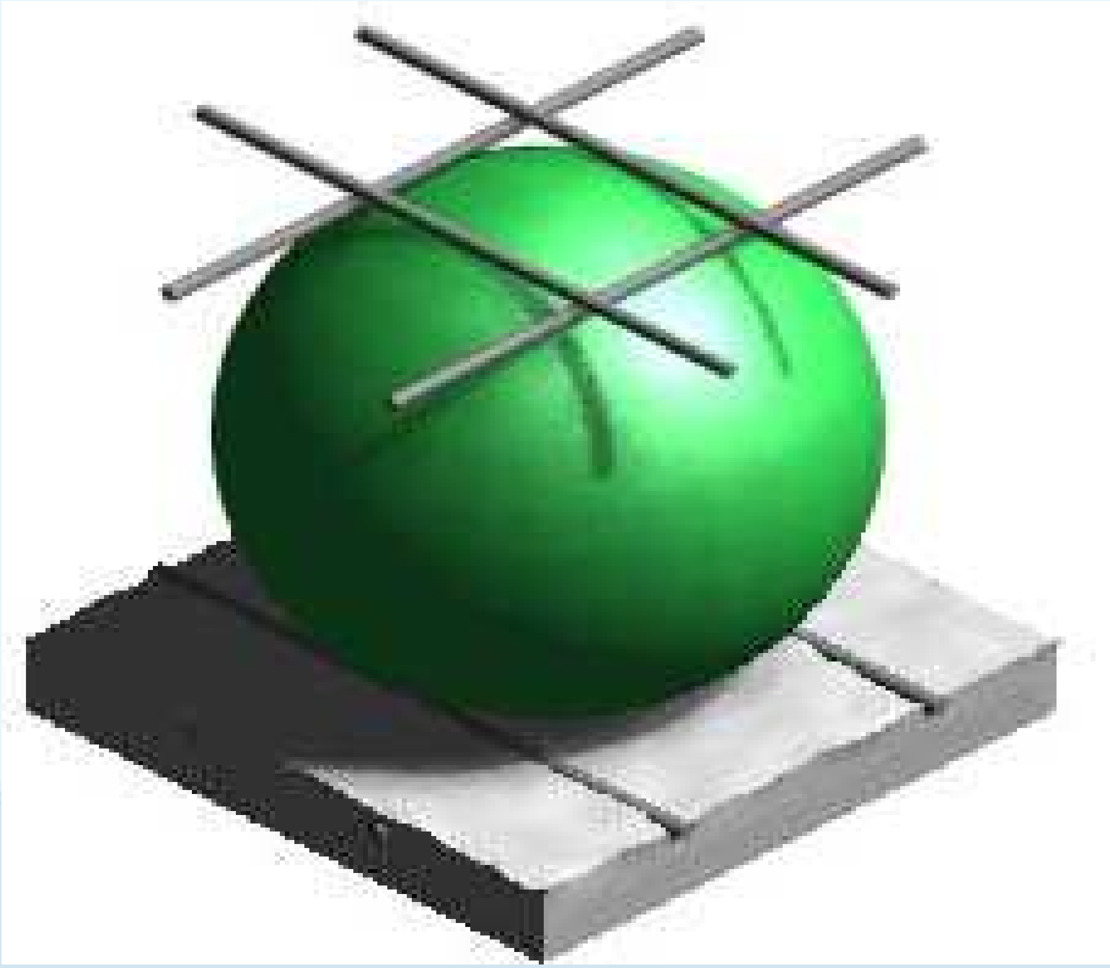
Dan Windorski, PE
GRAEF

Session sponsored by ACI 421

Voided Slab w/ precast stay in place form

- Voided Two-Way Flat Plate
- Use plastic spheres (bubbles) to displace concrete
- Designs and Behaves like monolithic concrete
- A merger of the best aspects of cast in place and precast concrete construction

Voided Slab w/ precast stay in place form



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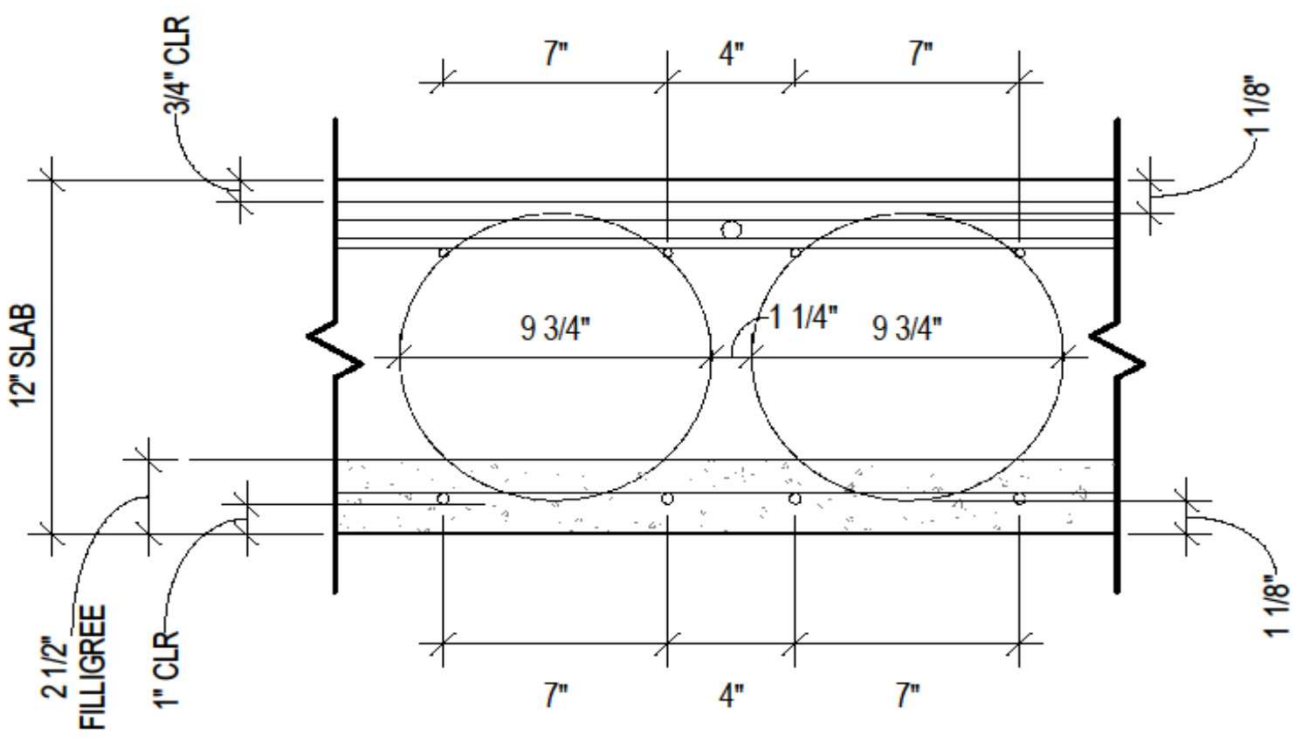

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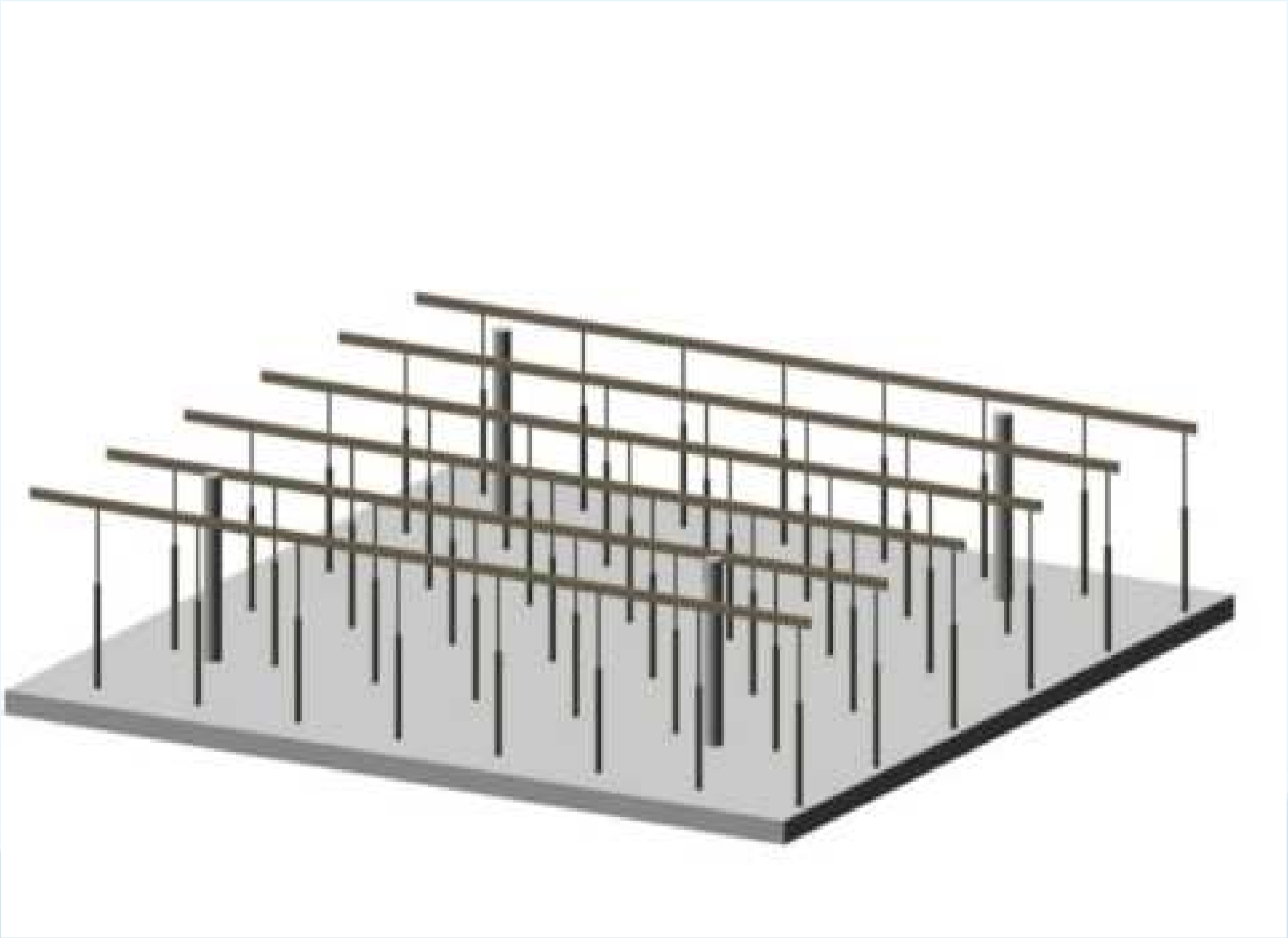

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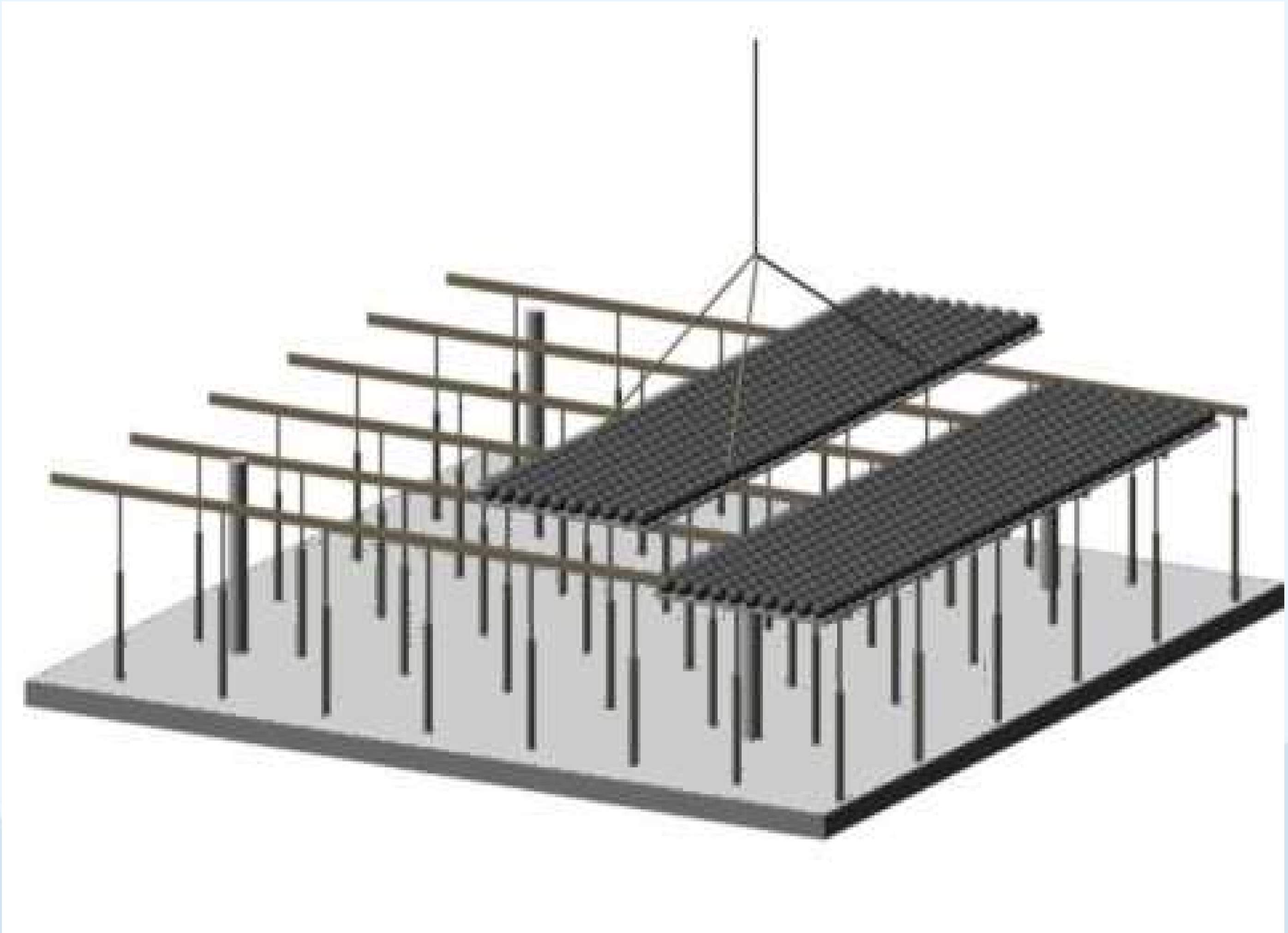

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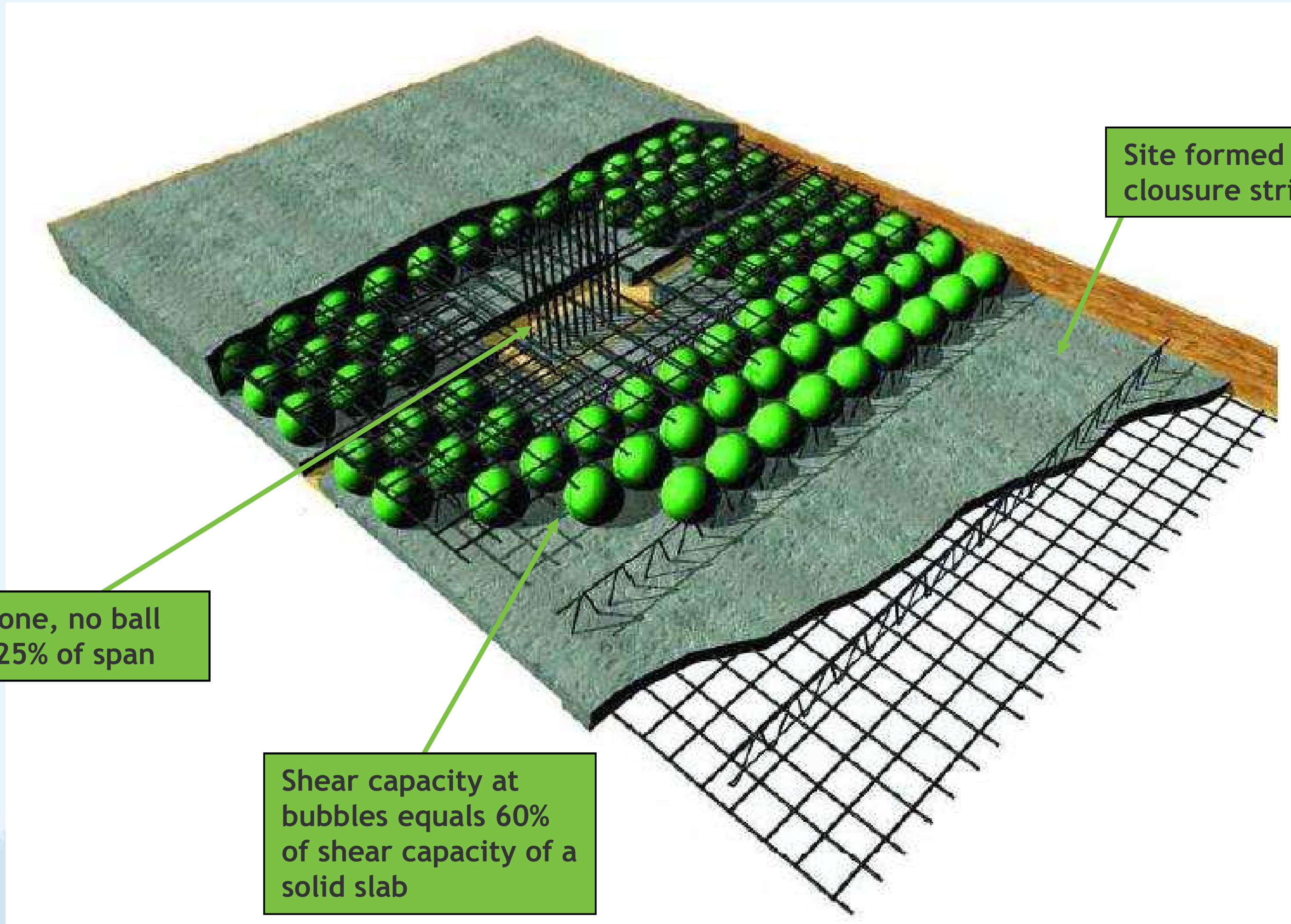

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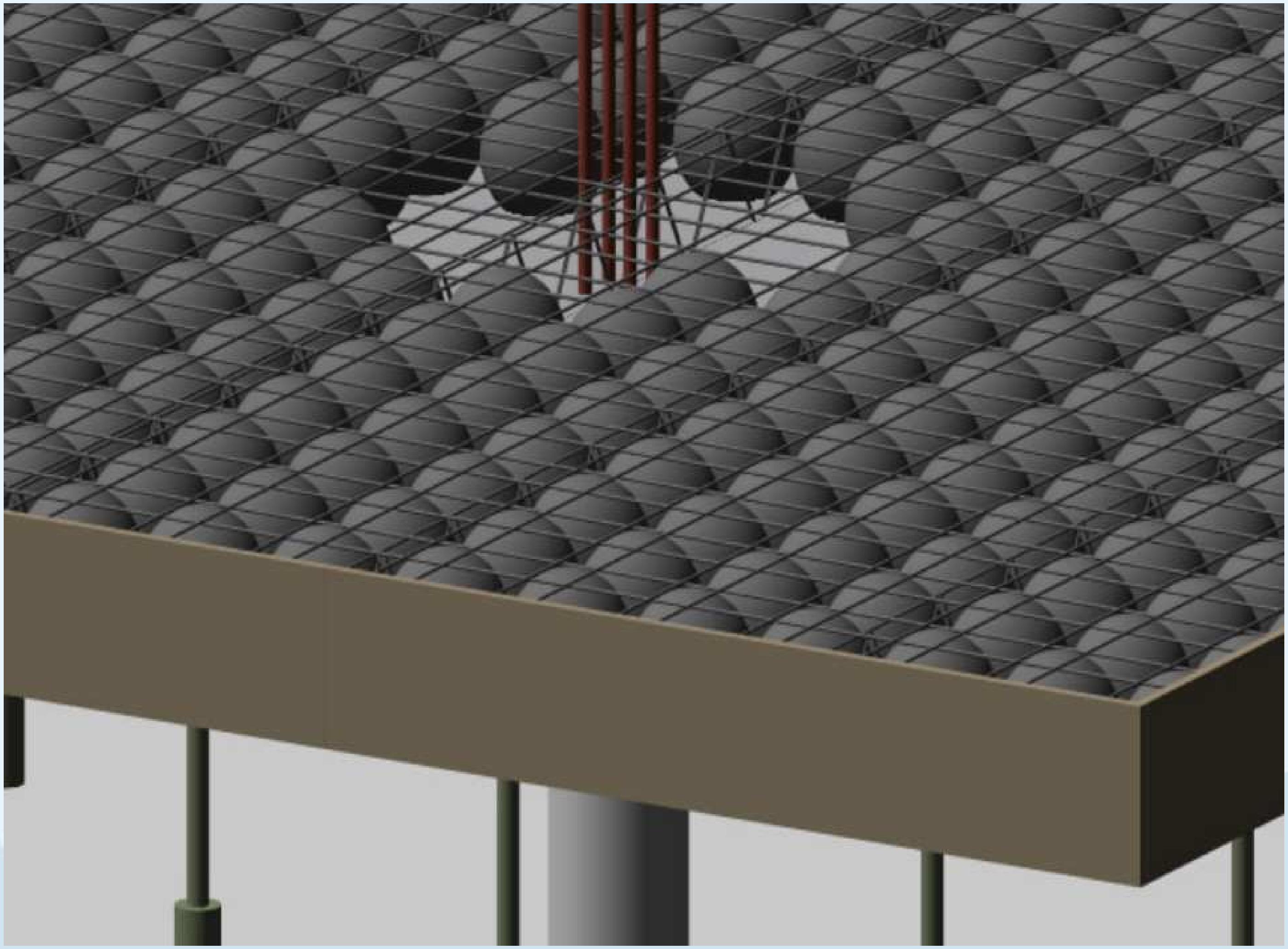

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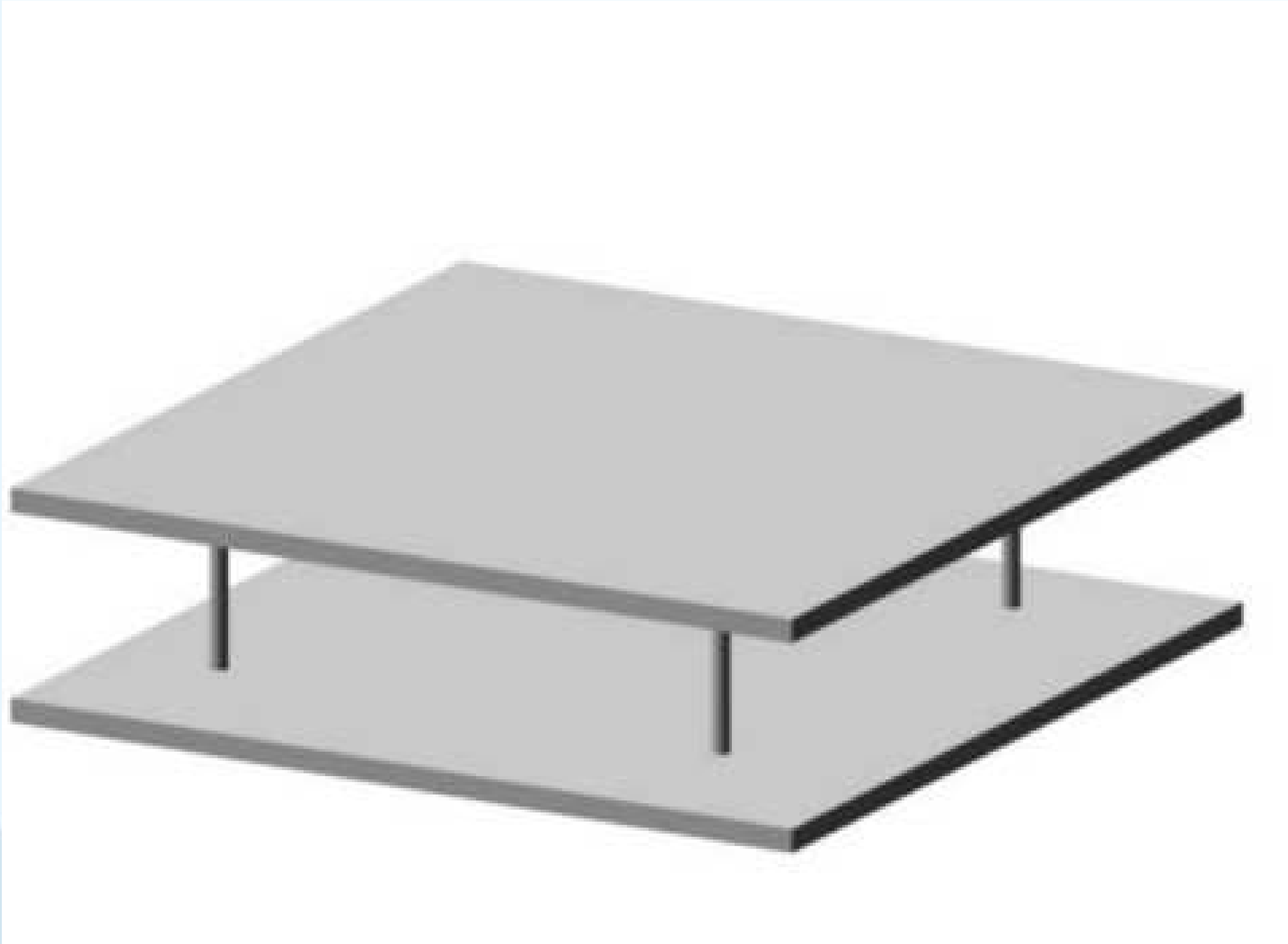
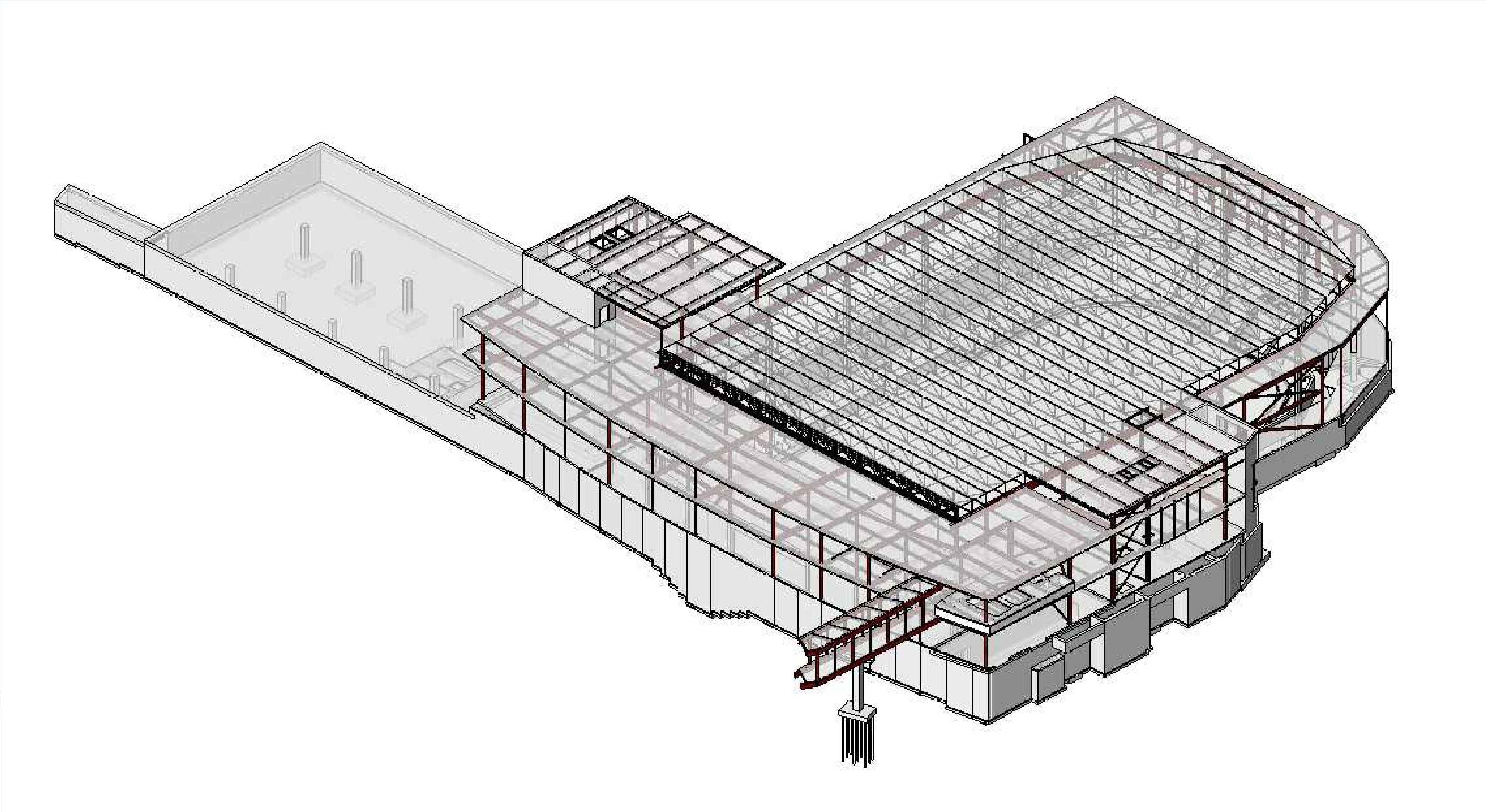


UW LaBahn Arena
Madison WI

BIM Structural Model – LaBahn Arena

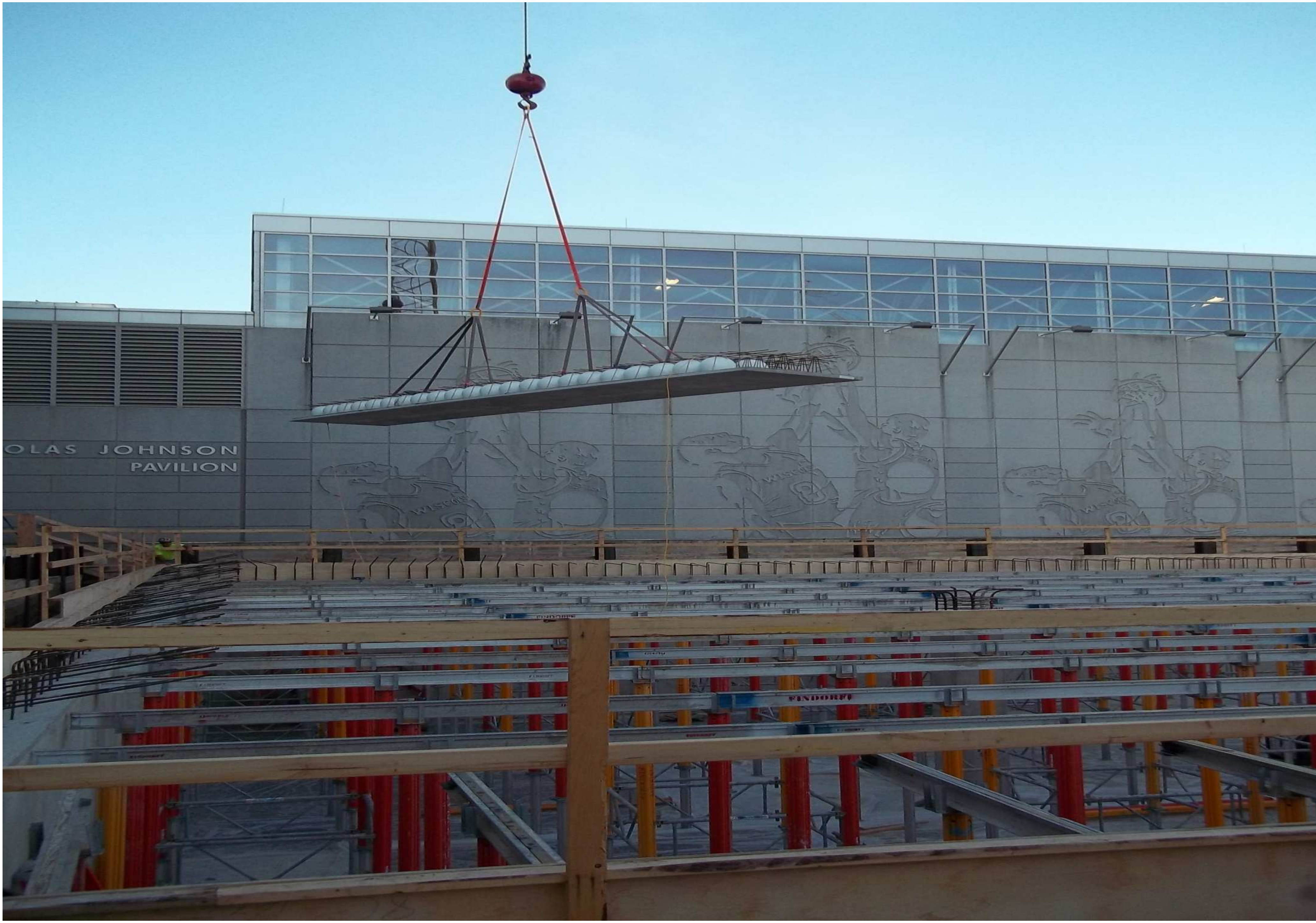


LaBahn Arena

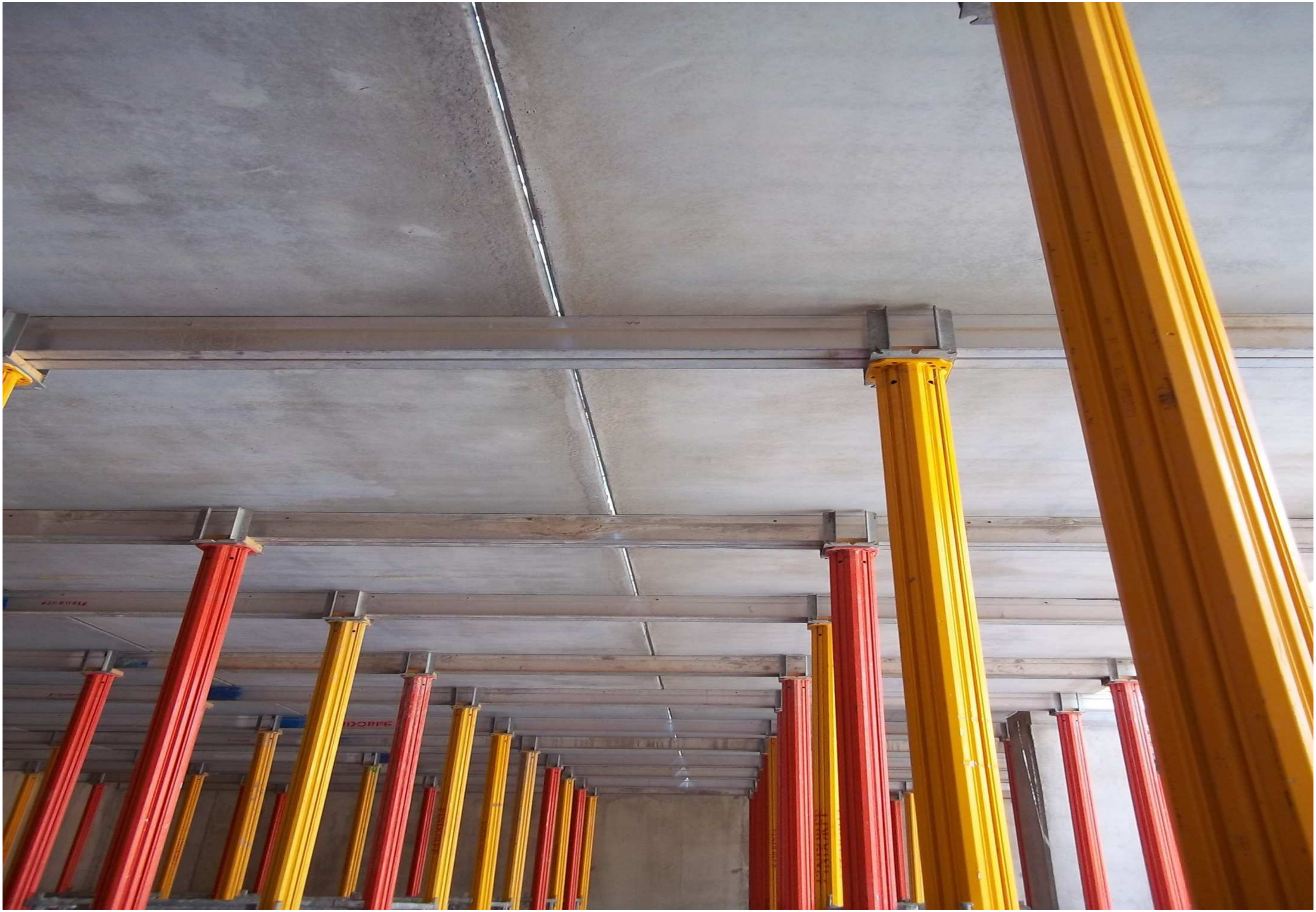
- 21 inch Voided slab
  - Plaza Slab
    - Supports 3.5 feet of soil
    - Designed for fire truck loading
- 11,000 Square Feet
- Serves as roof of Badger hockey locker rooms

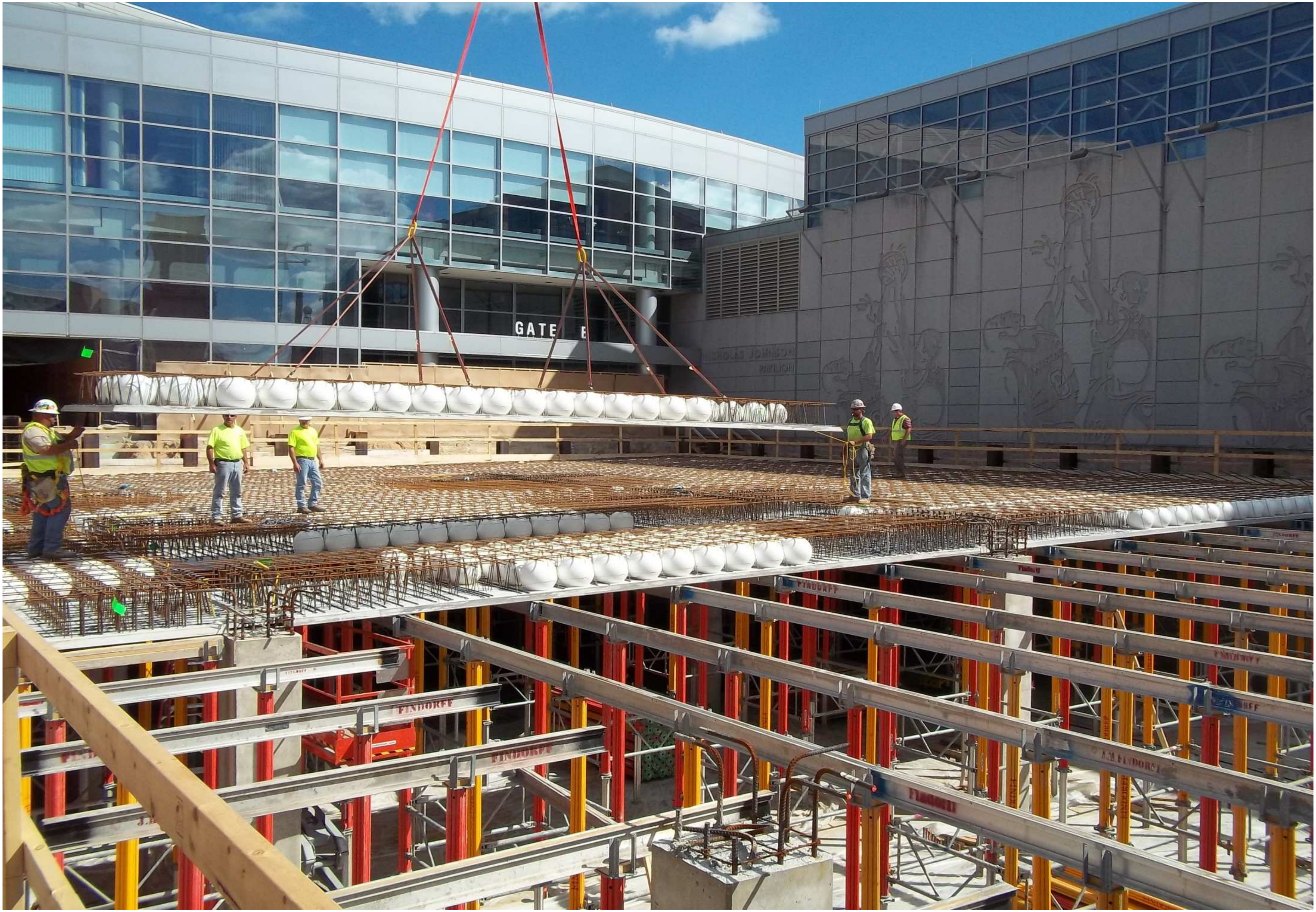
GATE B
NICHOLAS JOHNSON
PAVILION
FINDORFF


6556
AMSTON
TRAILER SALES
manac

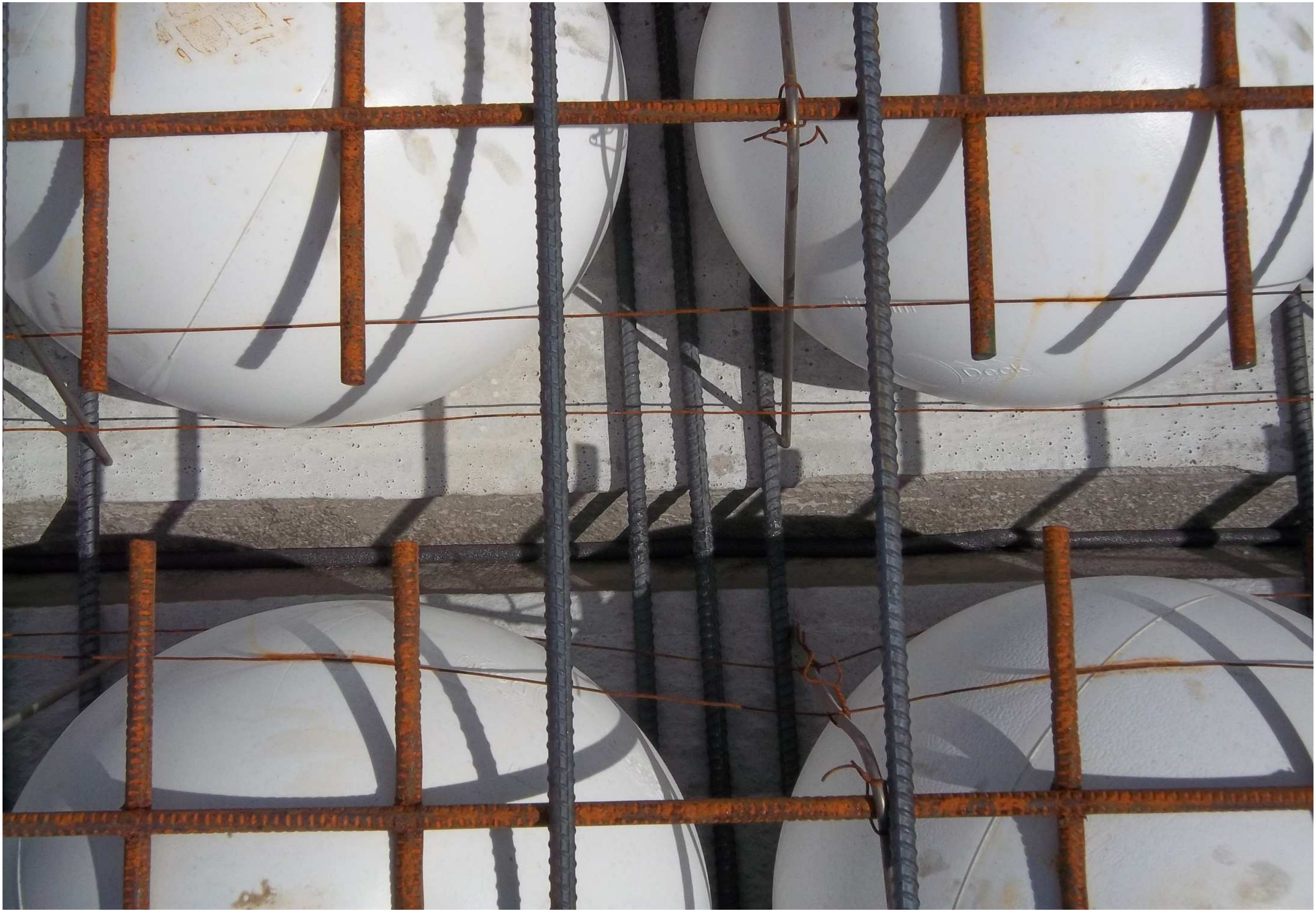

OLAS JOHNSON
PAVILION

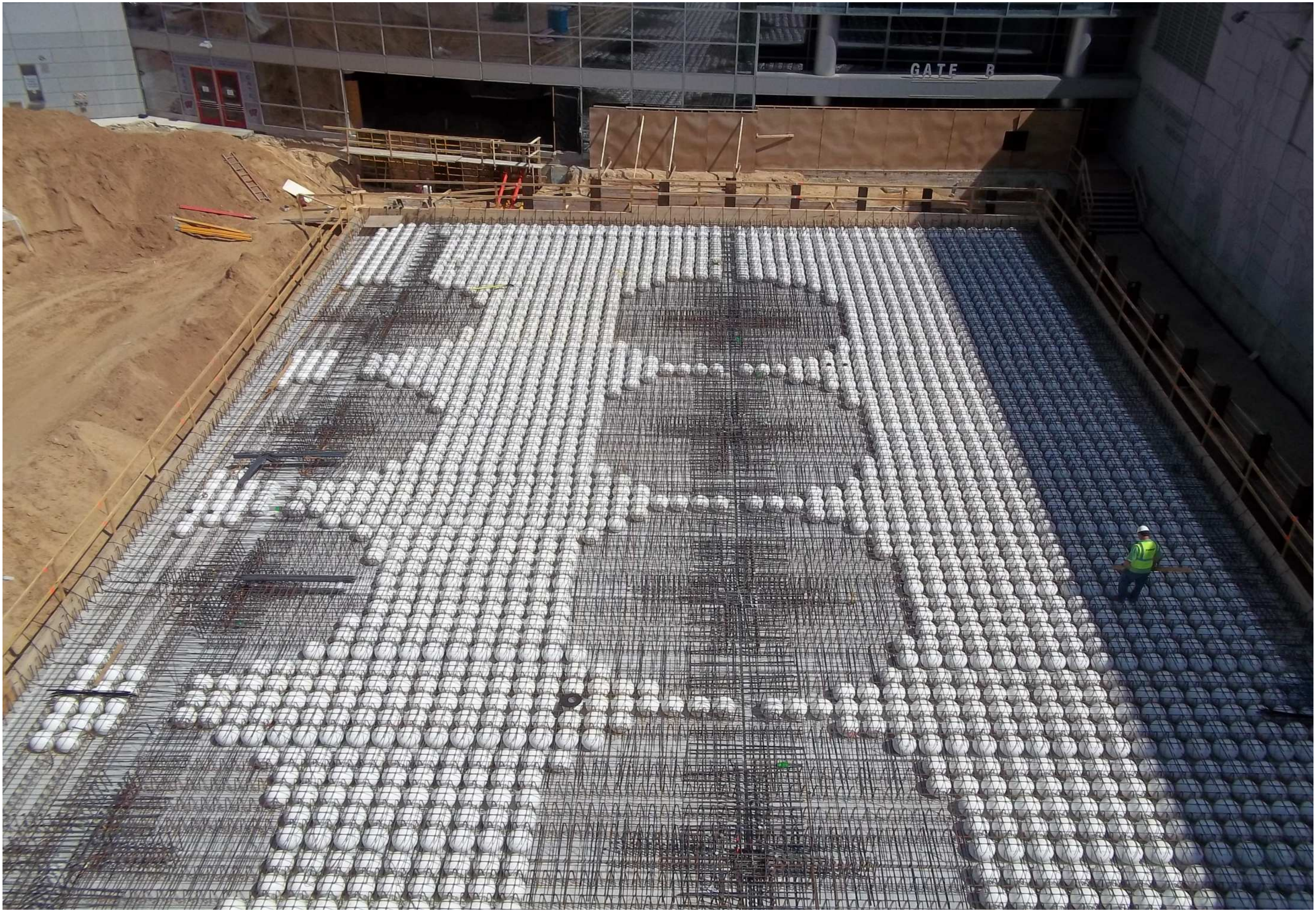

PAVILION
1-0859 BD-141
1-0859 BD-141

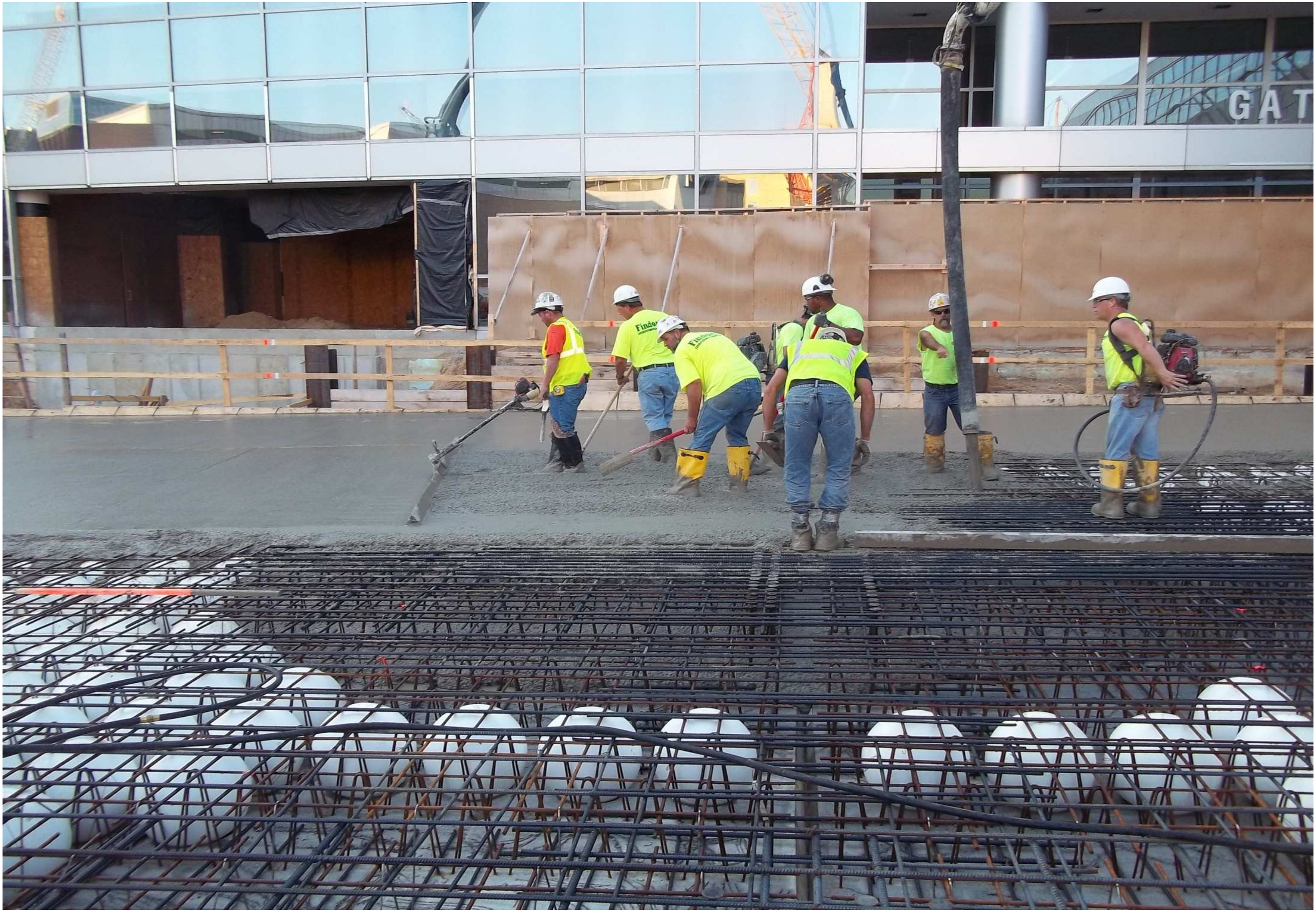



GATE E
FINDORFF


NO




GATE B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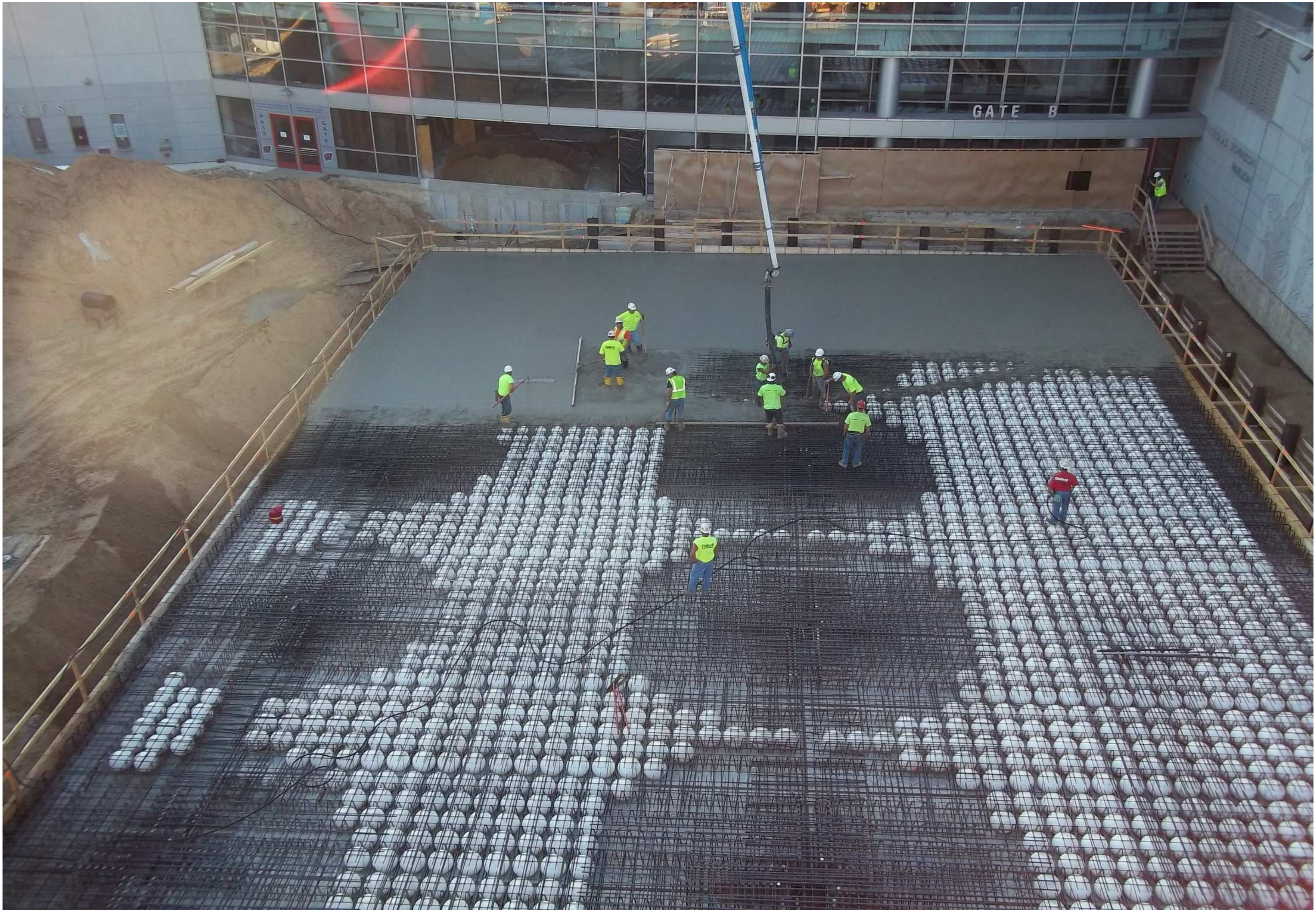

GATE B

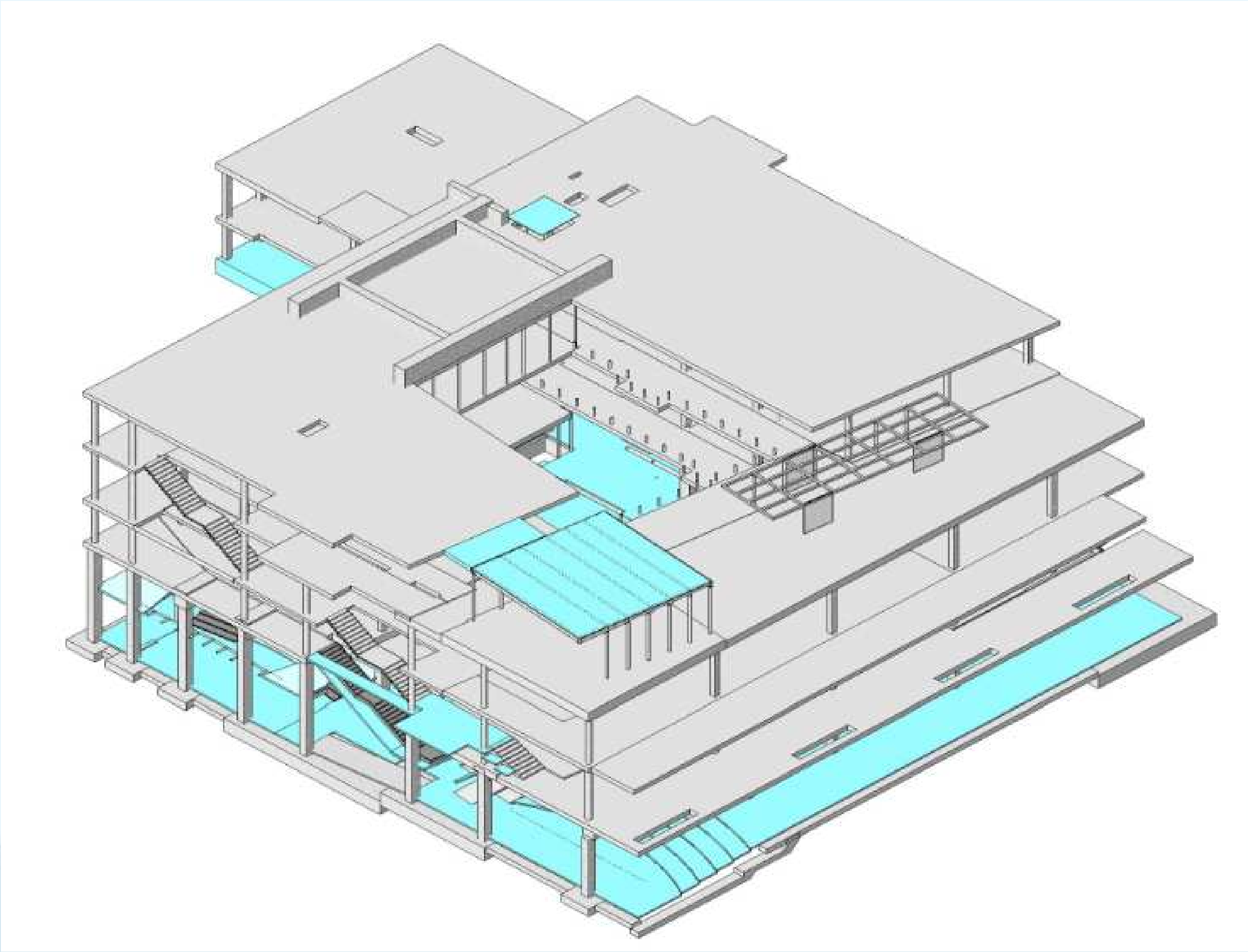

NICHOLAS JOHNSON
PAVILION

Why Voided Slab for UW LaBahn?

- Saved $2/SF
- Saved 174 CY of concrete
- Saved 3 days off of schedule
- Saved on shoring cost
- Saved structural depth

Harvey Mudd College
Teaching and Learning Building
Claremont, CA

BIM Structural Model – Harvey Mudd College

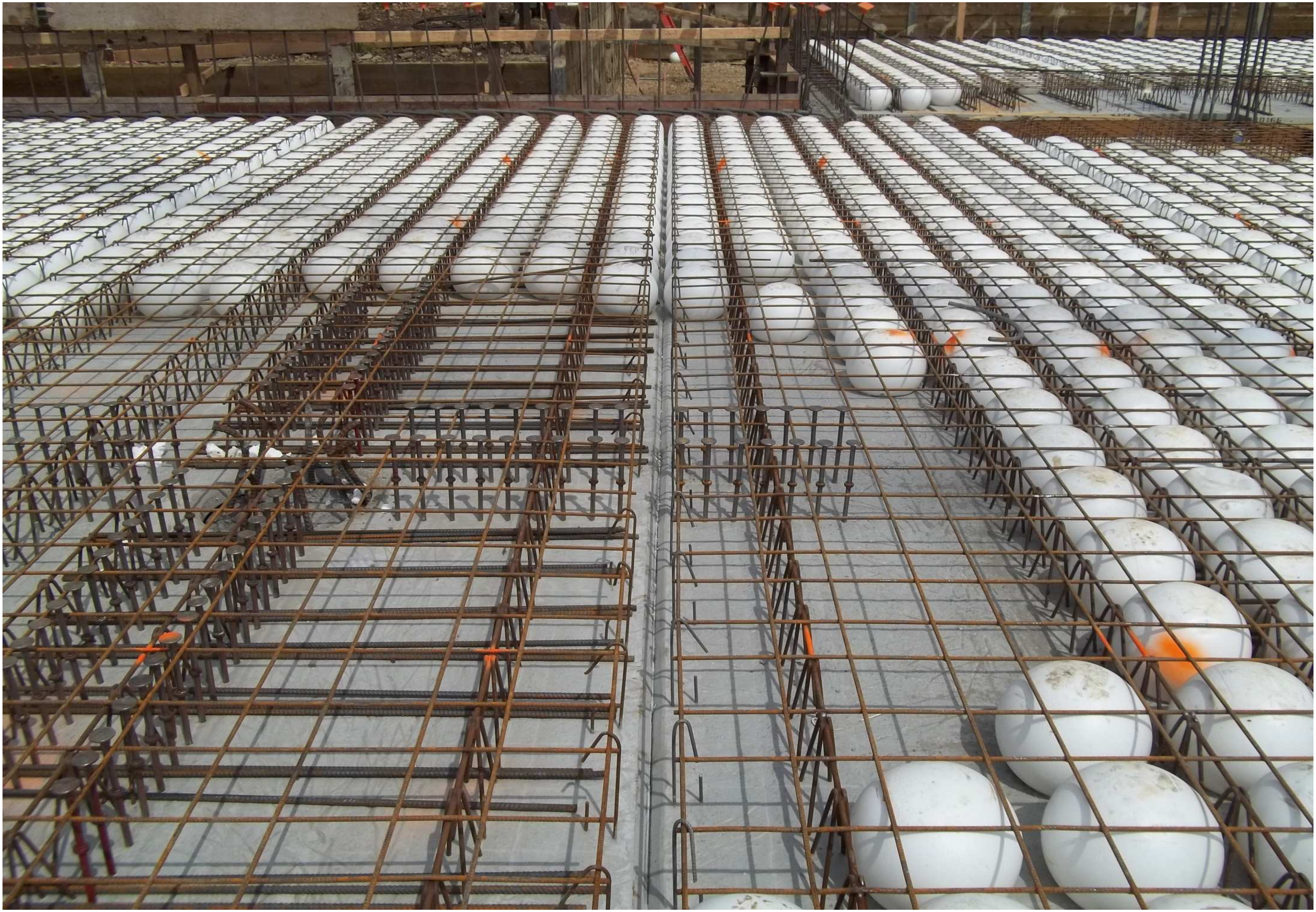


(courtesy of KPFF)

Harvey Mudd - TLC

- 4 –Story Education Building
- 80,000 square feet of Voided slab
- 9, 11, 13.5, 17.5 and 20 inch slab thicknesses used
- Located in high seismic zone


1 2 3 4 5 6 7 8 9 10 11




M
CSI
CAUTION

Why Voided slab for Harvey Mudd?

- Highly Visible Exposed Concrete Ceilings
- MEP Coordination/Pre-Installation
- Seismic Mass Reduced
- Long-term Deflection Considerations
- Saved 750 CY of Concrete

Watertown Regional Medical Center East Addition

Watertown, WI

Watertown Regional Medical Center

- Emergency Dept & Women's Health Addn
- 2-Story & 30,000 square feet
- Existing construction systems:
  - Concrete waffle slabs
  - Concrete pan joist
  - Precast concrete and steel beams
- System selection for healthcare facilities
  - Grid layout
  - Story height


Tyvek


920.261.1682

Why Voided slab for WRMC?

- Flexible and larger column grid
- Thin structural system leads to higher headroom for MEP/medical systems.
- Material savings
- Increased construction speed by minimizing on-site labor

Summary

- Form work is virtually eliminated. Fewer lines of shoring.
- The finished underside of the panel can be left exposed and untreated.
- Overall building height is minimized reducing building façade.

Summary Cont.

- Reduced site labor, increased safety.
- Less onsite concrete, quicker pour time.
- Core holes are faster to drill.
- Building is more efficient, reduced carbon footprint, has potential for LEED credits.